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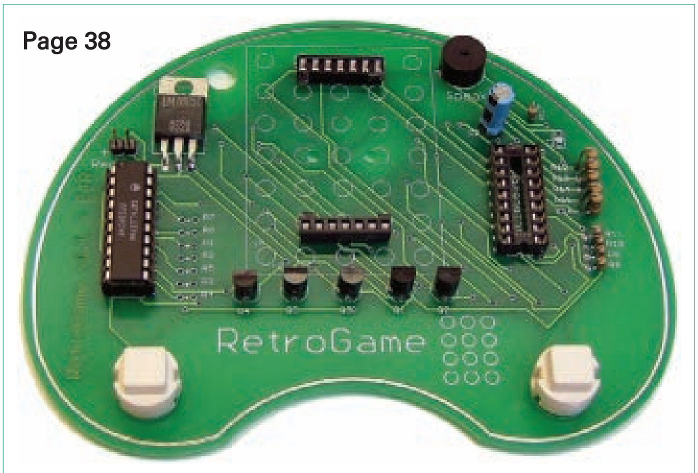

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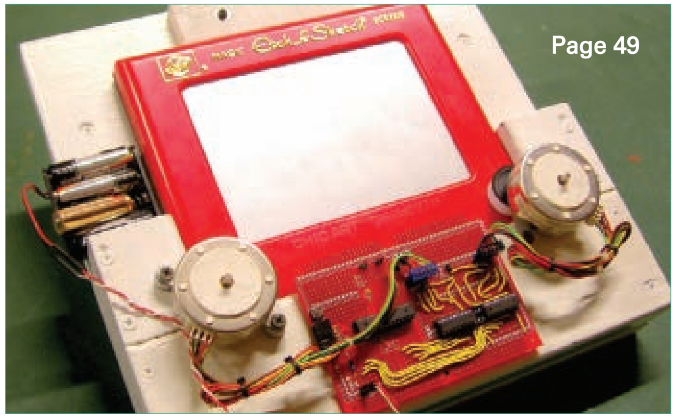

Departments

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DEVELOPING PERSPECTIVES

The Art of Diagnosis

When I first discovered my passion for electronics, my greatest frustration was that a circuit — whether a kit, from a magazine article, or my own design — wouldn't work as expected. More than one of my early creations ended up in a junk box, destined to be disassembled for parts. In retrospect, my frustration was unfounded. I eventually discovered that after gaining a degree of manual fluency working with components, breadboards, and a soldering iron, there wasn't much to be gained from a continuing string of successes.

Heresy, you say? Think about it. When was the last time you applied Ohm's Law when building a kit or following one of the schematics in *Nuts & Volts*? Or, determined the cutoff bias of a transistor? Or, tried to hunt down a ground loop in a printed circuit board? Real learning in electronics comes from the hours spent pouring over schematics and circuit boards using heuristics and a bit of luck to identify bad components and flawed designs. Even if you don't agree, this perspective will help you keep a positive attitude when faced with a seemingly impossible diagnostic challenge.

Mastering the art of diagnosis has benefits beyond successfully completing construction projects. Once you've mastered the art, no broken radio, appliance, or computer peripheral should be beyond repair. Furthermore, not only will you become an asset to your friends and family, but you may suddenly find yourself with a second income.

Given the current uncertain economy, having a second source of income — even if only enough to pay for your electronics habit — is a good thing. Electronics is one of the few hobbies universally useful enough to be revenue neutral.

Based on my experience, making the shift from hobbyist to professional can be imperceptible. My first real job in electronics — working as a technician for the Offshore Telephone Company — was like being paid to have fun. I would have done it for free, just to get my

hands on dual-trace oscilloscopes, digital meters, spectrum analyzers, and other extravagant test equipment that I couldn't even dream of affording.

Developing diagnostic skills in electronics or any other field requires more than bench time. In addition to reading the numerous articles in *Nuts & Volts*, you'll have to pick up a book or two to guide you on your journey. We feature several worthy titles in the *Nuts & Volts* Webstore. My all-time favorite author for honing electronics diagnostic skills is Forrest Mims III. If you're on a budget, consider one of the used, older books on Amazon or other online dealers. Modern components may be more compact and powerful, but the basics of diagnosis haven't changed in decades.

Another great source for learning electronics diagnosis is the American Radio Relay League (**www.arrl.org**). The *ARRL Handbook* is probably the place to start, even if you aren't interested in communications and how to set up a communications station. Again, look for a used copy online — other than the introduction of the memristor, the fundamentals haven't changed since the first printing of the *Handbook*.

To round out your library, consider the exceptional text, *The Art of Electronics*, by Horowitz and Hill. If you're at all serious about developing your diagnostic skills, you should have a copy of the '89 printing on your bookshelf. Because this text is intended to be used in the classroom, there are multiple examples of incorrect and problematic circuits for you to diagnose.

My last and most important suggestion is to identify and do your best to learn from a mentor — a teacher, a friend with more advanced skills, or an employer. A good book can present the science behind decision-making, but a good mentor will teach you the true art of electronics. **NV**

READER FEEDBACK

INSTRUMENTAL IN FINDING ERRORS

I really like Michael Bessant's model rocket articles and follow them very closely. The problem is that the January 2009 article *Instrumentation for Model Rocketry* does not have the correct schematic (page 35) for the new code (page 37). The schematic shown is from the August 2007 *N&V* (page 39). Michael is a very talented guy and I would love to see the correct schematic. Thank you for your help.

Tom Perry
Smyrna, GA

Response: Unfortunately, Tom's rather flattering comments about my abilities seem to be misplaced. Although the schematic is correct, I have introduced errors in the SYMBOL table that is at the start of the program. The correct icons required to make it match the original schematic are as follows:

symbol redled = 5
symbol download =7
symbol power = 2
symbol rate = 8

Please accept my apologies for any inconvenience these errors may cause you.

Mike Bessant

INSIGHT ON THE INSIDE

In Fred Eady's Design Cycle in the February 2009 issue, the Silicon Labs CP2103 chip was featured. Fred mentioned that if you wait long enough they might roll the caps and diodes into the chip, as well. As it turns out, many of those components can be eliminated if your intention is to only support RS-232! The CP2103 chip is designed to support RS-422 and GPIB capabilities also, and in doing so, requires more external capacitors and support parts than the RS-232 (only) CP2102 chip.

With the CP2102 chip, you only need two external capacitors and the ESD diodes! The extra capacitors associated with the CP2103 chip are

continued on page 75

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CAR KITS FOR ELECTRONIC ENTHUSIASTS

HAND CONTROLLER KIT

KC-5386 $37.95 + post & packing

This LCD hand controller is required during the initial setting-up procedure. It plugs into the main unit and can be used while the engine is either running or stopped. Using this Hand Controller, you can set all the initial parameters and also program the ignition advance/retard curve.

- Kit supplied with silk screened and machined case, PCB, LCD, and all electronic components.

DIGITAL FUEL ADJUSTER KIT

KC-5385 $50.95 + post & packing

This unit gives you complete control of the air/fuel ratio at 128 points across the entire engine load range and provides incredible mapping resolution and brilliant drivability. It uses the Handheld Digital Controller - KC-5386 (available separately) so there is no need for a laptop. Supports both static and real-time mapping.

- Kit supplied with a quality solder masked PCB with overlay, machined case with processed panels, programmed micro and all electronic components.

ECONOMY ADJUSTABLE TEMPERATURE SWITCH KIT

KC-5381 $18.95 plus postage & packing

It has an adjustable switching temperature (up to 245°C) and can be configured to trigger on rising or falling temperature. Useful for running cooling fans or over-temp warning lights or alarms, etc.

- Kit supplied with PCB, NTC Thermistor, and all electronic components.

UNIVERSAL VOLTAGE SWITCH KIT

KC-5377 $18.95 plus postage & packing

This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more.

- Kit supplied with PCB, & all electronic components.

FREQUENCY SWITCH KIT

KC-5378 22.95 plus postage & packing

This is a great module which can be adapted to suit a range of different applications. It uses a standard tacho, road speed, or many other pulse outputs to switch a relay. The switch frequency can be set to trip when it is rising or falling, and it features adjustable hysteresis (the difference between trigger on/off frequency). You could configure it to trigger water spray cooling on deceleration, shift light activation, adjustable aerodynamics based on speed, intake manifold switching and much more.

- Kit supplied with PCB, and all electronic components.

FUEL MIXTURE DISPLAY KIT FOR FUEL INJECTED CAR

KC-5374 $17.95 plus postage & packing

This kit features auto dimming for night driving, emergency lean-out alarm, and better circuit protection. Another great feature is the 'dancing' display, which operates when the ECU is operating in closed loop.

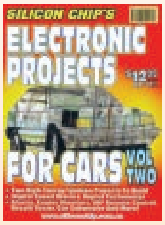
- Kit supplied with PCB and all electronic components.
- Car must be fitted with airflow and EGO sensors (standard on all EFI systems) for full functionality.

ELECTRONIC PROJECTS FOR CARS VOL. II

BS-5075 $9.75 plus postage & packing

This informative magazine contains a collection of 17 electronic projects for cars from Silicon Chip Magazines. The interesting articles and projects include:

- Ignition projects
- PIC-based projects
- Alarms & Engine monitors
- Limiters and Immobilisers
- Miscellaneous projects.
- 128 pages.



IMPROVED TACHOMETER KIT FOR CARS

KC-5290 $39.95 plus postage & packing

Unlike its' bulky predecessor from August 1991, this PIC based tachometer is housed neatly in a small jiffy box (83 x 54 x 31mm), which mounts nicely on your dashboard. It's amazing features include 4-digit LED display showing up to 9,900rpm in 100rpm increments, 10 LED bargraph with optional dot or bar mode (showing 8-independent rpm thresholds), calibration options for 1- 12 cylinder 4-stroke or 1- 6 cylinder 2-stroke engines, anti-display flickering feature and automatic night-time display dimming, to perform engine limiting.

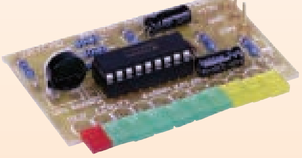
- Kit includes case with silk-screened panel, PCBs, pre-programmed PIC micro, 7-segment displays, red acrylic, hook-up wire and all electronic components.

CAR BATTERY MONITOR KIT

KA-1683 $10.95 plus postage & packing

Don't get caught with a flat battery! This simple electronic voltmeter lets you monitor the condition of your car's battery so you can act before getting stranded. 10 rectangular LEDs tell you your battery's condition.

- Kit includes PC board and all components.



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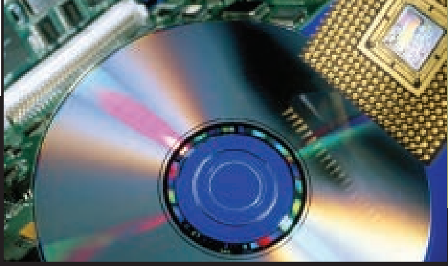


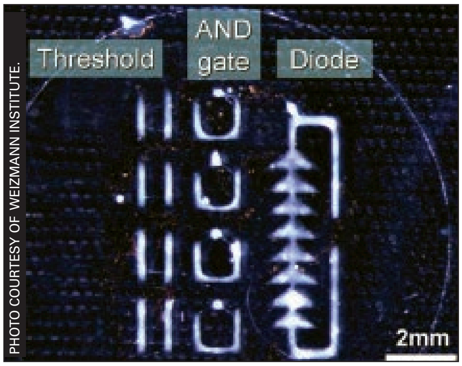
TECH KNOWLEDGEY 2009

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

"MEAT" FOR BRAINS FOR FUTURE ROBOTS?



■ Four thresholds, four AND gates, and a composite diode grown on a single 13 mm coverslip.

When neurons clump together in a big enough mass, they can end up forming a brain, which offers the ability to think, do arithmetic, process data, and so on. But if you pluck one off and drop it into a dish, it becomes stupid and unable to perform useful functions (much like what happens when you separate one member of a boy band from the rest). But what happens if you put them (the neurons, that is) back together? Could we not assemble a functional artificial neural network made up of live neurons? Scientists at Israel's Weizmann Institute of Science (**www.weizmann.ac.il**) seem to have proven the affirmative, at least on a small scale. In an early experiment, Prof. Elisha Moses and his team created two "wires" made up of about 100 axons each and connected them to a small number of nerve cells. When the cells received a signal along just one of the wires, the result was uncertain, but when the signal was carried by both wires, there was a clear-cut response. Thus, Moses et al. created a living AND gate.

Further research has produced more complex functions, so it now seems reasonable to project ahead and imagine a robot fitted with a functional brain that is grown in a lab and made of "meat" rather than silicon and software.

According to Moses, "We have been able to enforce simplicity on an inherently complicated system. Now we can ask, `What do nerve cells grown in culture require in order to be able to carry out complex calculations?' As we find answers, we get closer to understanding the conditions needed for creating a synthetic, many-neuron `thinking' apparatus."

Here philosophy meets science: Does such a brain actually think? Is it intelligence or artificial intelligence? Or artificial artificial intelligence? Is the robot in which it resides a conscious being or a lifeless machine? When you're done with it, does it go to a scrap dealer or an old robot's home? And your imagination doesn't have to stop there.

In a seemingly unrelated activity, the folks at PETA are offering a $1 million prize to anyone who can grow in vitro chicken meat and sell it to the public. (If you think I'm kidding, see **www.peta.org/pdfs/In_Vitro_Contest_Rules.pdf**.) So what if Prof. Moses and Perdue Farms get together and come up with a boneless chicken breast with a brain? Is it still ethical to eat it?

It's getting weirder out there.

RODENT POWER!

In another development sure to stir up PETA's ire, Prof. Zhong Lin Wang with the Georgia Tech School of Materials Science and Engineering has demonstrated a way to use rodents as a renewable source of electricity. It appears that hamsters — being especially energetic and active — are the prime candidates. (Predictably, rats turned out to be less willing to participate.) The concept is actually applicable to almost any kind of irregular mechanical movement, including finger tapping, a flag flapping in the breeze, and the vibration of your vocal cords after an anvil lands on your foot. In the rodent-based demonstration, Wang placed a nanogenerator in a little jacket, slipped Mr. Hamster into it, and set him to running in an exercise wheel.

■ This hamster was recruited to demonstrate conversion of biomechanical energy to electricity.

The generator works through the piezoelectric effect. Zinc oxide wires, encased in a flexible polymer substrate, are anchored at each end with an electrical contact plus a Schottky barrier at one end to control current flow. Flexing the substrate produces alternating current, although not very much of it — four of the generators produced only 0.5 nA. At that level, it would take thousands of them to drive a simple Bluetooth device.

Nevertheless, "We believe this is the first demonstration of using a live animal to produce current with nanogenerators," Wang stated. "This study shows that we really can harness human or animal motion to generate current."

COMPUTERS AND NETWORKING

NEXT TOP SUPERCOMPUTER

Toward the end of 2008, the world's fastest supercomputer was still the 1.105 petaflop IBM

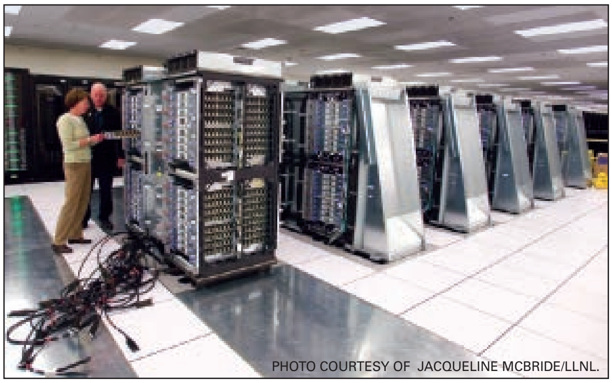


PHOTO COURTESY OF JACQUELINE MCBRIDE/LLNL.

■ LLNL staff inspect a newly installed rack for Dawn, which will pave the way for the 20TFLOP Sequoia.

"Roadrunner" machine housed at the Los Alamos National Laboratory. Close behind was the Cray XT5 at the Oak Ridge National Laboratory, called "Jaguar." The latter — only the second to break the petaflop/s barrier — posted a top performance of 1.059 petaflop/s in running the Linpack benchmark application. Pretty impressive, but now the Department of Energy's National Nuclear Security Administration (NNSA, **nnsa.energy.gov**) has announced a contract with IBM to bring even faster machines to the Lawrence Livermore National Lab (**www.llnl.gov**) to help ensure the safety and reliability of the nation's increasingly aging nuclear deterrent.

IBM will deliver two systems: Sequoia, a 20 petaflop system based on future BlueGene technology, to be delivered starting in 2011 and deployed in 2012; and an initial delivery system called Dawn, a 500 teraflop BlueGene/P system, which should already be delivered by the time you read this. Dawn will be used to develop applications for multi-petaflops computing on Sequoia. Under the hood, Sequoia will have 1.6 petabytes of memory, 96 racks, 98,304 compute nodes, and 1.6 million cores. How fast is 20 petaflops?

According to NNSA, "If each of the 6.7 billion people on Earth had a hand calculator and worked together on a calculation 24 hours per day, 365 days a year, it would take 320 years to do what Sequoia will do in one hour."

CATCH A WORM, GET $250,000

In October of last year, a computer worm called Conficker (a.k.a., Downup and Dowandup) began creating havoc by exploiting a vulnerability in the Windows Server service used by various versions of the operating system. Within a compromised computer, it disables several defensive services and connects to a remote server, which feeds it marching orders to steal personal information and propagate itself. It also installs more malware on your machine. Reportedly, Conficker had infected nearly 9 million machines by the middle of January. Well, if you have the expertise, it's time to put on your Sherlock Holmes hat and do some digital sleuthing.

As part of a "partnership with technology industry leaders and academia to implement a coordinated, global response to the Conficker worm," Microsoft is offering a $250,000 reward for information that results in the arrest and conviction of those responsible for launching the malicious code. Hopefully, the culprits will be brought to justice soon. In the meantime, information about how to protect yourself from Conficker can be found at **www.microsoft.com/conficker**.

CIRCUITS AND DEVICES

SATELLITE CONSTELLATION SURVIVES COLLISION

Although the usual conspiratorial theories abound, it looks like a pure accident that a defunct Russian Kosmos-2251 satellite collided with one operated by Iridium Satellite LLC (**www.iridium.com**) in February, thus creating a hole in their worldwide telephone service. Within a day or two, Iridium announced that the hole had been patched, and service disruptions were over. However, aftereffects will continue, as the event contributed to a long-term problem: it created tens of thousands of pieces of space junk, weighing close to a ton and a half, that could circle the Earth and threaten other vehicles for as long as 10,000 years. In fact, the US military already tracks something like 900 active satellites and 17,000 pieces of debris, but only chunks larger than about two to four inches. But even pieces as small as a centimeter can damage or destroy a space vehicle.

In response, the United Nations Office for Outer Space Affairs (UNOOSA, **www.oosa.unvienna.org**) promptly called on all member states and international organizations to implement measures to curb space debris.

By the way, if you're thinking about replacing your cell phone with a satellite one, be advised that there's a price to be paid. The new Iridium model 9555 will run you about $1,600, and you'll pay about $2 per minute to use it (although prepaid blocks of minutes can bring that down).

You also can't use it indoors, and there is a noticeable delay in conversations, as the signal has to travel to the satellite and then to an earthbound gateway before it reaches your receiver. And vice versa from the other end of the conversation. But satellite phones remain up and running during hurricanes and other disasters, so

■ An Iridium satellite.

INDUSTRY AND THE PROFESSION

MICROSOFT RETAIL VENTURE

For years, Microsoft has shied away from the idea of opening up its own retail stores, but it recently hired David Porter — a former Wal-Mart bigwig — to take it in that direction. The move is likely inspired by the success of Apple stores, of which the company now has more than 200. But Apple got into the retail business out of necessity; having nearly faded away as a serious PC competitor, the chain stores were pulling its products from the shelves. Microsoft has no such problem. So is it a good idea?

Well, **news.com** conducted a poll of its readers and their responses, as of this writing, were as follows. (1) Yes, it worked for Apple, it will work for them: 7.7%. (2) Yes, they need a place to show their wide product range: 25.3%. (3) No. It's a terrible time to be going into retail: 25.5%. (4) Who cares? I still won't buy anything from them: 41.4%. Oh, well.

SO LONG, OLD FRIEND

At the 1939 World's Fair, President F. D. Roosevelt gave the opening day address, and his speech was broadcast by NBC to a whopping 200 television sets, viewed by about 1,000 people. Thus, regular analog programming was launched. The *New York Times* observed, "The problem with television is that ... the average American hasn't got time for it." Seventy years later (February 17), the Funeral for Analog TV was held at the Berkeley Art Museum to mourn the loss of our old friend.

The eulogy read, in part, "Born in the 1920s, the signal has been an integral part of all our lives, bringing us news of the rich, the famous, the politicians, the wars, the Apollo landings, the thrills of victory, and the agonies of defeat. While Analog Television has not been a good friend to us all, it has been important to each and every one of us. Analog Television is survived by its wife Digital Television, and its second cousin Internet Television."

As it turns out, broadcasters were not required to shut down on February 17 as expected. At the last minute, Congress yanked the do-not-resuscitate order and spared ATV until June 12. But the disease is terminal, so that old coat hanger with the aluminum foil wrapped around it won't work much longer.

MUZAK NEWZ

Alas, the same can't be said of Muzak LLC (**www.muzak.com**), the company that for 75 years has tortured shoppers and elevator riders with mind-numbing, syrupy renditions of real music. Going into Chapter 11 bankruptcy, the company cited assets of $324 million and liabilities of $465 million. Unfortunately, it will continue to pipe out the squishy mood music while it lays off 1,250 employees and otherwise tries to reduce costs and increase revenues.

reliability and coverage will offset the disadvantages for some users.

DANGEROUS PRINTER PARTICLES

Another form of hazardous particles has been identified in a new study at Australia's Queensland University of Technology (**www.qut.edu.au**). Apparently, particles emitted from common laser printers are potentially dangerous to human health, because they can penetrate deep into the lungs.

In a recently published paper, Prof. Lidia Morawska of the university's International Laboratory for Air Quality and Health revealed that different printers emit different levels of toner glop, depending on both the heat of the fuser and the rate of temperature changes. No details were provided in the public statement about the specific harmful effects or how individual printers ranked, but such information is presumably contained in the paper itself. You can get it at **http://pubs.acs.org/doi/abs/10.1021/es802193n**, but it will cost you $30 for 48 hours of access time. **NV**

■ BY FRED EADY

OLDER LANGUAGE, NEWER INTERFACE

C IS A VERY VERSATILE PROGRAMMING LANGUAGE. However, it's a sure bet that there are plenty of you out there that work wonders with the Basic programming language. Believe it or not, I can write Basic programs too, but being able to cobble together tricky Basic statements is useless without hardware that is capable of converting those words into real world actions. So, this month we're going to design and assemble the hardware necessary to support a powerful Basic language variant: ZBasic. In the process, we're also going to add another USB device to your Design Cycle.

ANOTHER USB INTERFACE IC

In a previous edition of Design Cycle, we explored the virtues of the Silicon Laboratories CP2102 and CP2103 USB-to-UART-bridges. For the ZBasic USB hardware, we're going to jump ship and row across the bay to the FTDI camp. The CP210X devices are perfect for general-purpose USB to RS-232 conversions. When it comes to the ZBasic hardware platforms, the FTDI FT232R USB UART IC is a better fit.

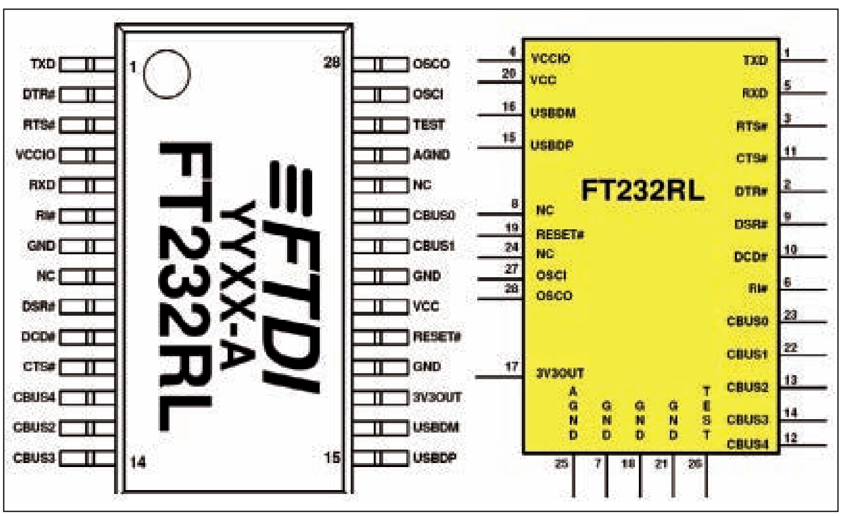
Like the Silicon Laboratories USB interface ICs, the FT232R is a single chip solution that encapsulates the USB protocol. If you had the opportunity to participate in our CP210X discussion, you'll recall that I really liked the simplicity of the CP210X supporting circuitry. The FT232R follows suit in that department. The FT232R integrates the USB termination resistors, the clock, the crystal, and configuration EEPROM. Data rates between 300 bps and 3 Mbps are supported by an internal 256 byte receive buffer and 128 byte transmit buffer. The FT232R is also considered a "drop-in" replacement for the industry standard RS-232 conversion ICs and is suitable for use with the RS-232, RS-485, and RS-422 protocols. Like anything complicated, it is often best to understand smaller subsystems to gain a working knowledge of the complete system. So, we'll examine the FT232R as groups of associated pins. Let's take a walk around the FT232R USB UART IC using Figure 1 as a guide.

THE USB INTERFACE GROUP

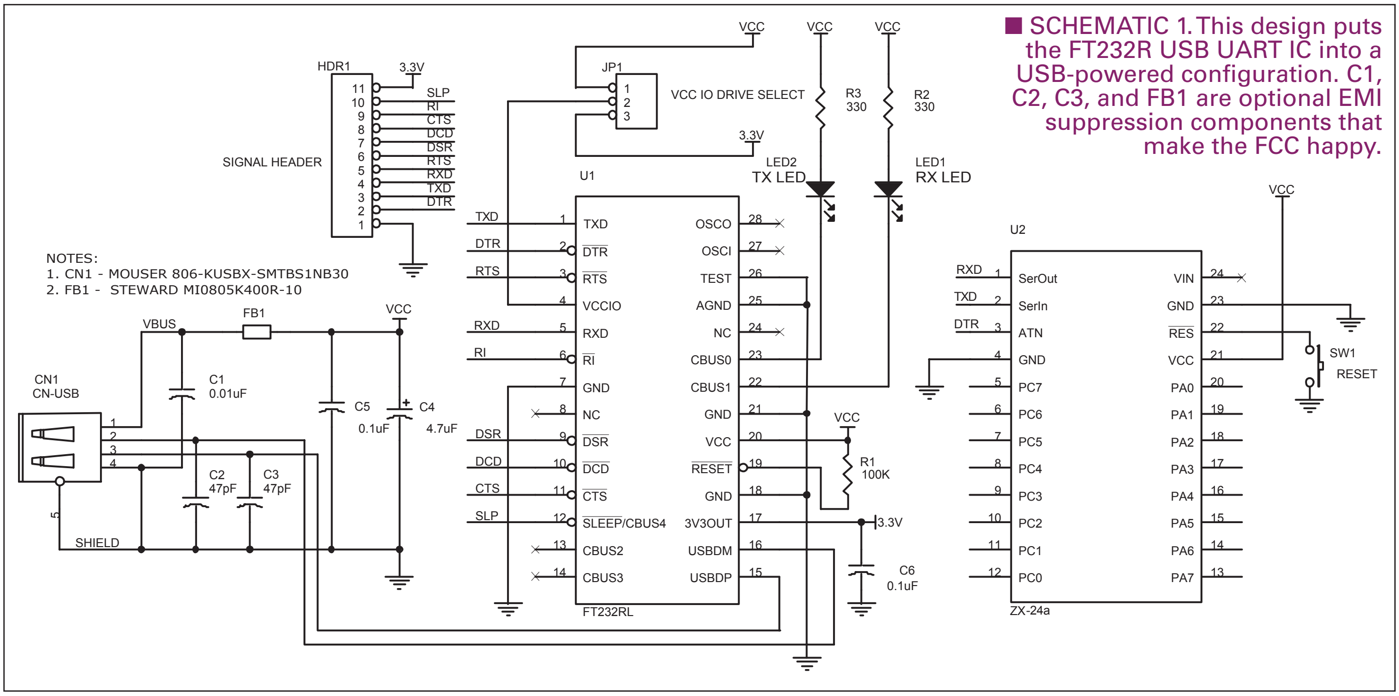
Pins 15 and 16 form the FT232R USB UART IC's USB interface. The USBDP (USB Data Signal Plus) input is supported by an internal series and pullup resistor pair. The same configuration holds true for the USBDM (USB Data Signal Minus) pin with the exception of the pullup resistor.

THE POWER GROUP

The FT232R USB UART IC's pin 4 is used to determine the output drive levels of the UART interface and the CBUSx pins. When the FT232R is used in a USB bus powered circuit, we can tie the VCCIO pin to the 3V3OUT pin to drive the outputs at +3.3 volt levels. Otherwise, tying the VCCIO pin to VCC (+5.0 VDC) will result in an output drive level of +5 volts. The FT232R can also be persuaded to drive its outputs as low as +1.8 volts



■ FIGURE 1. The FT232R USB UART IC looks busy here. However, it doesn't take much to use it to build a simple RS-232 to USB converter. The secret to the FT232R IC's success is that it is just as configurable on the inside as it is on the outside.



■ SCHEMATIC 1. This design puts the FT232R USB UART IC into a USB-powered configuration. C1, C2, C3, and FB1 are optional EMI suppression components that make the FCC happy.

by supplying the VCCIO pin from an external regulated supply. The only rule that must be followed for the low voltage external reference supply is that it is obtained from a regulator that is fed from the original VCC bulk supply.

The voltage on the 3V3OUT pin is a product of the FT232R's integrated LDO (Low DropOut) regulator. In addition to supplying a reference for the VCCIO pin, the LDO regulator is there to provide +3.3 volts to the USB transceiver module and feed the USBDP pullup resistor. If the current requirement is kept below 50 mA, you can use the 3V3OUT voltage to power external circuitry.

We must supply at least +4.0 volts to the VCC pin to utilize the UART IC's internal clock generator. This requirement is easily met by feeding the VCC pin from the USB interface's VBUS signal.

THE UART INTERFACE AND CBUS GROUP

The UART interface signals are defined as follows:

TXD	Transmit Data Output
DTR	Data Terminal Ready Output
RTS	Request To Send Output
RXD	Receive Data Input
RI	Ring Indicate Input
DSR	Data Set Ready Input
DCD	Data Carrier Detect Input
CTS	Clear To Send Input

As far as the ZBasic hardware is concerned, we'll only employ the services of TXD, RXD, and DTR signals. The DTR signal is used as an ATN signal during download operations.

There are five configurable CBUS I/O lines (CBUS0-CBUS4). The I/O function of each CBUS line is configured using the IC's internal EEPROM. Our ZBasic hardware design uses CBUS0 and CBUS1 as the transmit and receive LED drive lines, respectively. CBUS I/O lines CBUS2 and CBUS3 are unused with CBUS4 indicating an FT232R SLEEP condition, which is analogous to a USB SUSPEND state.

Any of the CBUS I/O pins can be configured as the active-low transmit enable line (TXDEN) in an RS-485 application. The same is true for power control. All of the CBUS I/O lines have the option of being configured as PWREN (Power Enable) pins. In the PWREN mode, the selected CBUS pin is used to drive an external P-channel MOSFET switch. It is recommended that devices requiring high current levels be switched using the PWREN signal and associated circuitry.

THE MISCELLANEOUS GROUP

There's not much to say about this set of pins as most of them are not connected in our ZBasic hardware design. Our design ties the active-low RESET input to VCC with a 100K pullup resistor. Otherwise, the TEST pin is grounded as per the datasheet and the OSCO and OSCI pins are left unconnected.

DESIGNING THE FT232R HARDWARE

Putting together an FT232R circuit consists of two tasks with the first task dealing with the hardware design. There are a number of hardware configurations that the IC can assume. As you know, I like to keep things as simple as possible. In this case, that means that I would prefer to mount and solder as few components as possible.

Since we're designing around a USB interface, we

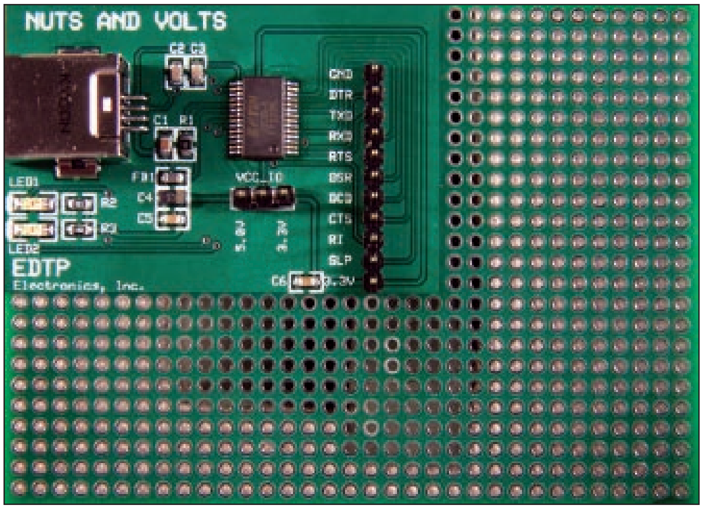
may be able to eliminate the need for an external regulated power supply. Thinking this out, the ZBasic ZX-24a module we will be interfacing with is based on an Atmel microcontroller. I'll get up on my donkey here and declare that the ZX-24a can't possibly draw any more than 100 mA. In fact, I don't think it will even draw near 50 mA. If I don't get thrown off the donkey, my assumptions on ZBasic hardware current drain fall well within the current levels that the USB interface can provide.

Moving forward with our donkey-riding theories sets our FT232R USB UART IC into a USB-powered hardware configuration. I've laid out the components for USB-powered mode in Schematic 1.

The trio of capacitors (C1-C3) and the ferrite bead (FB1) are mounted to suppress EMI. The ferrite bead helps reduce the noise that is radiated down the USB cable. The power supply source (VCC) for the entire design — including the ZBasic ZX-24a module — is taken from the USB VBUS interface pin. Capacitors C4 and C5 are acting as power supply filter capacitors. Extracting power from the VBUS line is fine as long as we don't exceed 500 mA of total drain and keep initial connection current drain less than 100 mA.

Jumper block JP1 enables the selection of the FT232R's output drive voltage, while all of the UART interface signals are terminated at header HDR1. The transmit and receive LEDs are eye candy and can be omitted from the design. However, the LEDs are invaluable in the debugging process. So, I've laid in pads for them and their current limiting resistors on my version of the ZX-24a USB interface.

The UART interface to the ZBasic module consists of only three lines. This interface is easily realized due to the FT232R's ability to morph the polarity of its UART interface. Morphing brings us to the second task, which is configuring the FT232R USB UART IC.



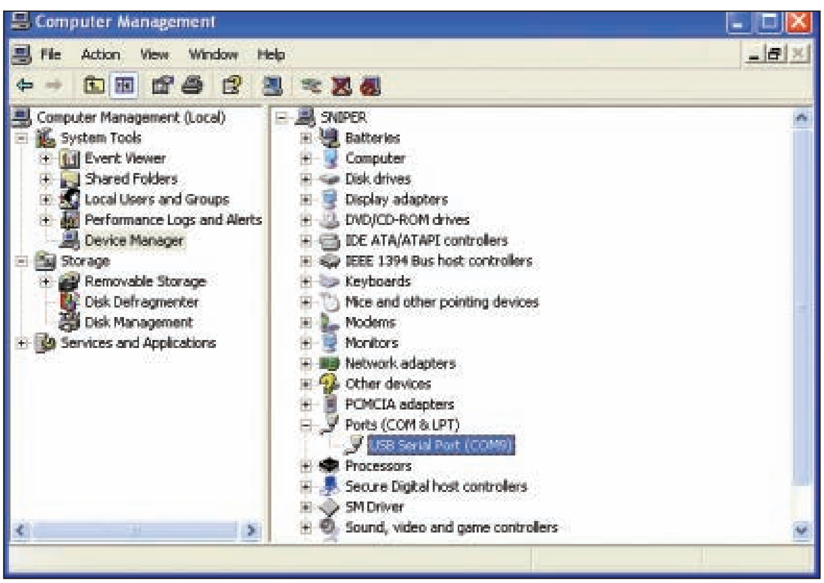
■ PHOTO 1. The components are small, but easy to mount and manually solder. When I mount the ZX-24a, I'll place a jumper block across the center and 5.0 V pins of the VCC_IO jumper block.

CONFIGURING THE FT232R

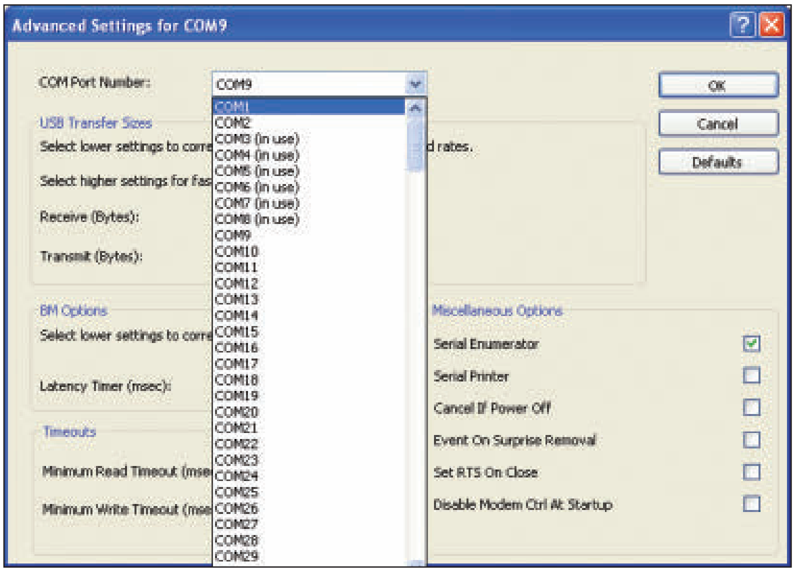
We must first assemble a working piece of FT232R-based USB interface hardware before we can access the internal configuration EEPROM. The graphical components of Schematic 1 sans the ZX-24a module are converted to physical form in Photo 1. The ExpressPCB file for the USB interface you see here can be found in the download package for this edition of Design Cycle on the *Nuts & Volts* website (**www.nutsvolts.com**).

Following the assembly of the USB interface, the next step is to load up the FTDI PC driver for the IC. Once you get the FT232R driver loaded, I suggest forcing the COM port setting for the USB interface to COM1. To do this with Windows XP, right-click on My Computer, select Manage, and Device Manager. For instance, after connecting my laptop to the prototype board, the FT232R driver initialized with a COM9 serial port interface. I highlighted the COM9 declaration as shown in Screenshot 1 and right-clicked on it. That took me to a menu containing Properties, which I clicked on. Once in the COM9 Properties window, I selected the Port Settings tab and clicked the Advanced button. If you followed that all correctly, you should see the window I've captured in Screenshot 2. At this point, select COM1 and proceed. Back out and perform all of the steps again beginning with right-clicking on My Computer. You should now have COM1 assigned in the Computer Management window.

With the USB hardware checked out, the FT232R driver loaded, and the desired COM port dialed in, we can download an application called MProg from the FTDI website. The MProg application runs on your PC and provides a view into the FT232R USB UART IC's configuration EEPROM. The first time I ran MProg, I opted to load the



■ SCREENSHOT 1. To get here with Windows XP, right-click on *My Computer*, select *Manage*, and then click on *Device Manager* in the Computer Management window. If your PC doesn't have a permanent COM port, you won't see this until you connect to the FT232R on the prototype board.



■ SCREENSHOT 2. By default, the ZBasic IDE wants to open COM1 and run at 19200 bps. So, why not accommodate it?

Default.ept file. After loading that configuration, I transferred from Program Mode to Edit Mode and modified the default template to meet the requirements of the ZX-24a.

As you can see in Screenshot 3, MProg gives us the power to alter the polarity of the UART signals and the functionality of the CBUS I/O lines. The ZX-24a requires that the TXD, RXD, and DTR signals be inverted. The reason for this lies in the fact that the ZX-24a utilizes inverters as its UART TTL interface instead of the TTL side of an RS-232 conversion IC. You can also see how the CBUS I/O configuration is accomplished. To push this configuration into the FT232R sitting on our ZBasic prototype board, we must save this group of settings and re-enter Program Mode.

The FT232R-based USB interface we just assembled and configured can be used in a multitude of applications. However, our target is the ZBasic ZX-24a hardware module. Let's wire one in.

THE ZX-24A

The ZX-24a is basically an Atmel AVR ATmega644 microcontroller supported by a set of 74HC04 inverter gates and a Flash memory device. The idea is to put just enough support stuff around the AVR microcontroller to enable it to be integrated easily into a useful application. You can almost piece together a ZX-24a system diagram by identifying the components that make up Photo 2. For instance, you can easily pick out the voltage regulator (U4), the Flash device (U2), the 74HC04 inverter package (U3), and the AVR (U1). The pair of on-board LEDs can be seen in the upper right corner of the printed circuit board (PCB). A complete ZX-24a schematic diagram is free as a download from the ZBasic website.

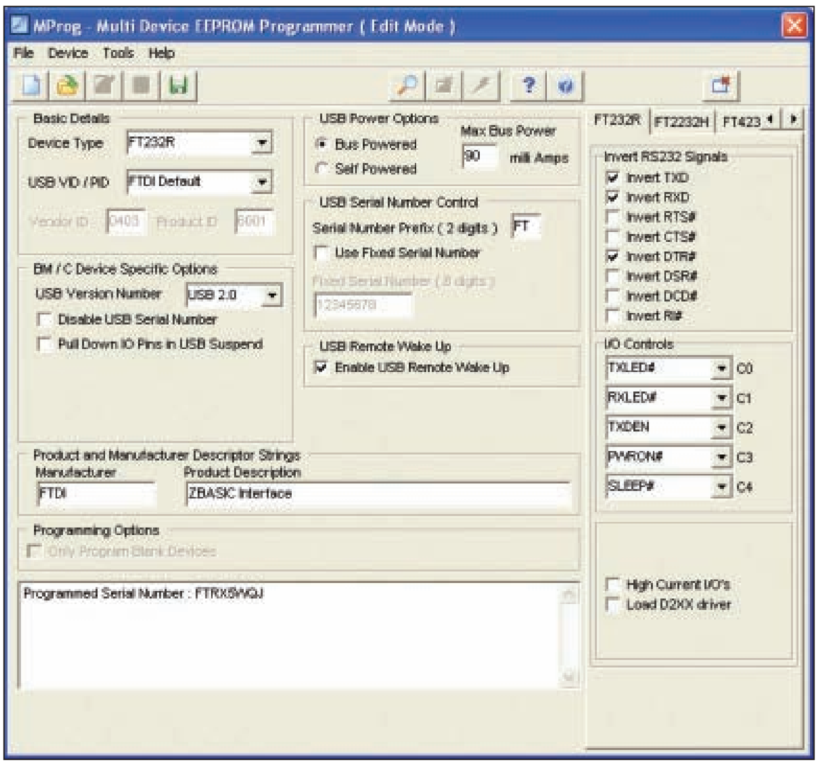
If you're familiar with the BASIC Stamp or the BX-24, you'll be right at home with the ZX-24a as it is pin compatible with both of the Stamp variants I just mentioned. With the ZX-24a, you have 3.5 KB of user RAM and 2,016 bytes of internal EEPROM available to your application. As you would expect, the ZX-24a also exposes the ATmega644's serial, analog-to-digital, and timer resources with routines contained within the ZBasic System Library.

Although the ZX-24a is equipped with an onboard voltage regulator, the ZX-24a documentation advises against using it. An external +5 volt regulator is the preferred power source. Our ZX-24a prototype design is powered entirely from the USB interface's VBUS line. The FT232R-based USB interface also provides TTL-level serial and control signals tailored especially for the ZX-24a's UART interface. If USB isn't part of your plans, the ZX-24a is also capable of directly connecting to a PC serial port.

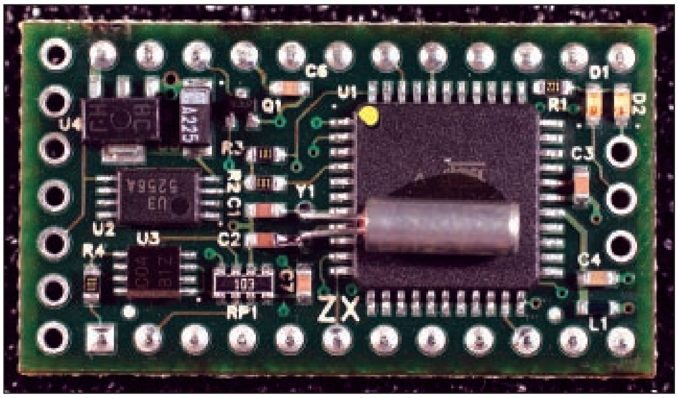
It took about five minutes to wire in the ZX-24a riding to the right of the FT232R UART signal terminations you see in Photo 3. I also added a reset switch and a jumper block on the VCC_IO selection header. If I don't release the ZX-24a's magic smoke with the insertion of a USB cable, we will be ready to exercise the ZX-24a with some ZBasic source code.

HERE WE GO

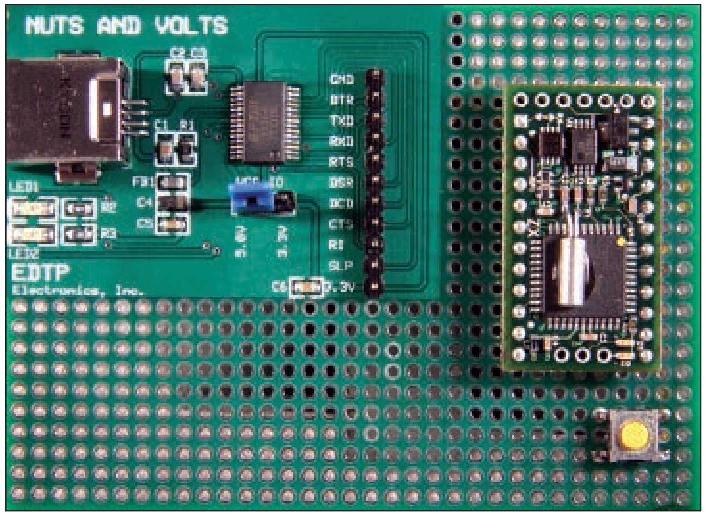
All through the hardware build, I was



■ SCREENSHOT 3. The ability to invert the UART interface signals allows us to design the FT232R USB UART IC into most any RS-232 to USB conversion application.



■ PHOTO 2. There's no rocket science in the hardware design of the ZX-24a. The Atmel-based hardware is simply a pawn under the control of the all-powerful ZBasic programming environment.



■ PHOTO 3. With the addition of a jumper block, a reset switch, and a ZX-24a module, we're ready to rock with ZBasic. I used wire wrap wire and point-to-point soldering assembly techniques to electrically attach the ZX-24a to the FT232R USB UART IC

hoping that someone had loaded a little demo program on my ZX-24a module. With total faith in my FT232R circuitry, I inserted a USB cable between the ZX-24a prototype board and my laptop. To my surprise, the ZX-24a's onboard LEDs began to flash in an alternating pattern. I figured if someone had gone to the trouble of blinking the LEDs, there was probably some serial data floating around out there, as well. Sure enough, I fired up a Tera Term Pro session on COM1 at 19200 bps and captured the message in Screenshot 4.

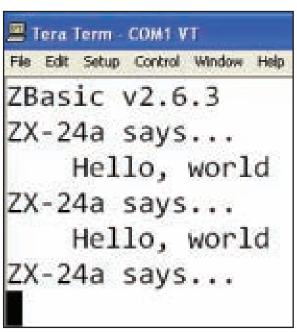
During my "It's Alive!" celebration, I observed that the FT232R's RX LED was flashing in step with each transmitted message. After some thought, I came to the conclusion that this is a correct indication. The FT232R is actually receiving the message from the ZX-24a.

SING A SIMPLE SONG

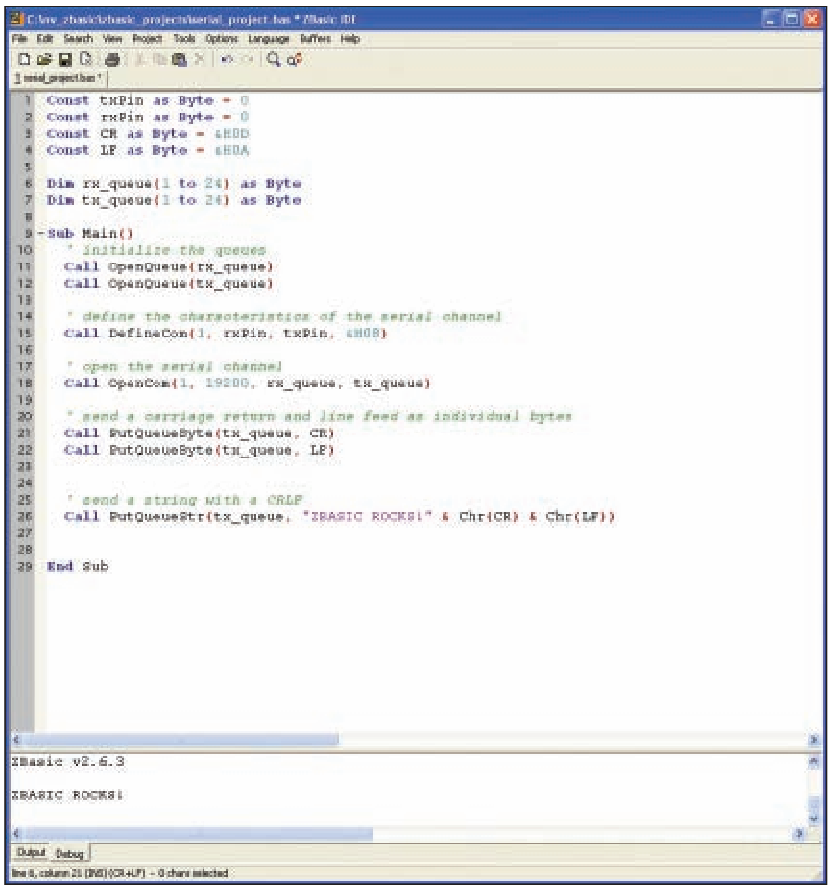
Once you invest in the ZBasic hardware platform of your choice, just about everything else you need to write ZBasic applications is free for a download. I downloaded and installed the ZBasic IDE and immediately clicked on the Debug tab at the bottom left of the IDE window. Lo and behold there was my "Hello, world" message chirping right along just as it had in the Tera Term Pro window. Let's try our luck at sending a message of our own.

The only subroutine that is absolutely required by a ZBasic program is *main()*. Otherwise, ZBasic is based on programming patterns found in Visual Basic 6. We'll begin our ZBasic program by defining the transmit and receive I/O pins:

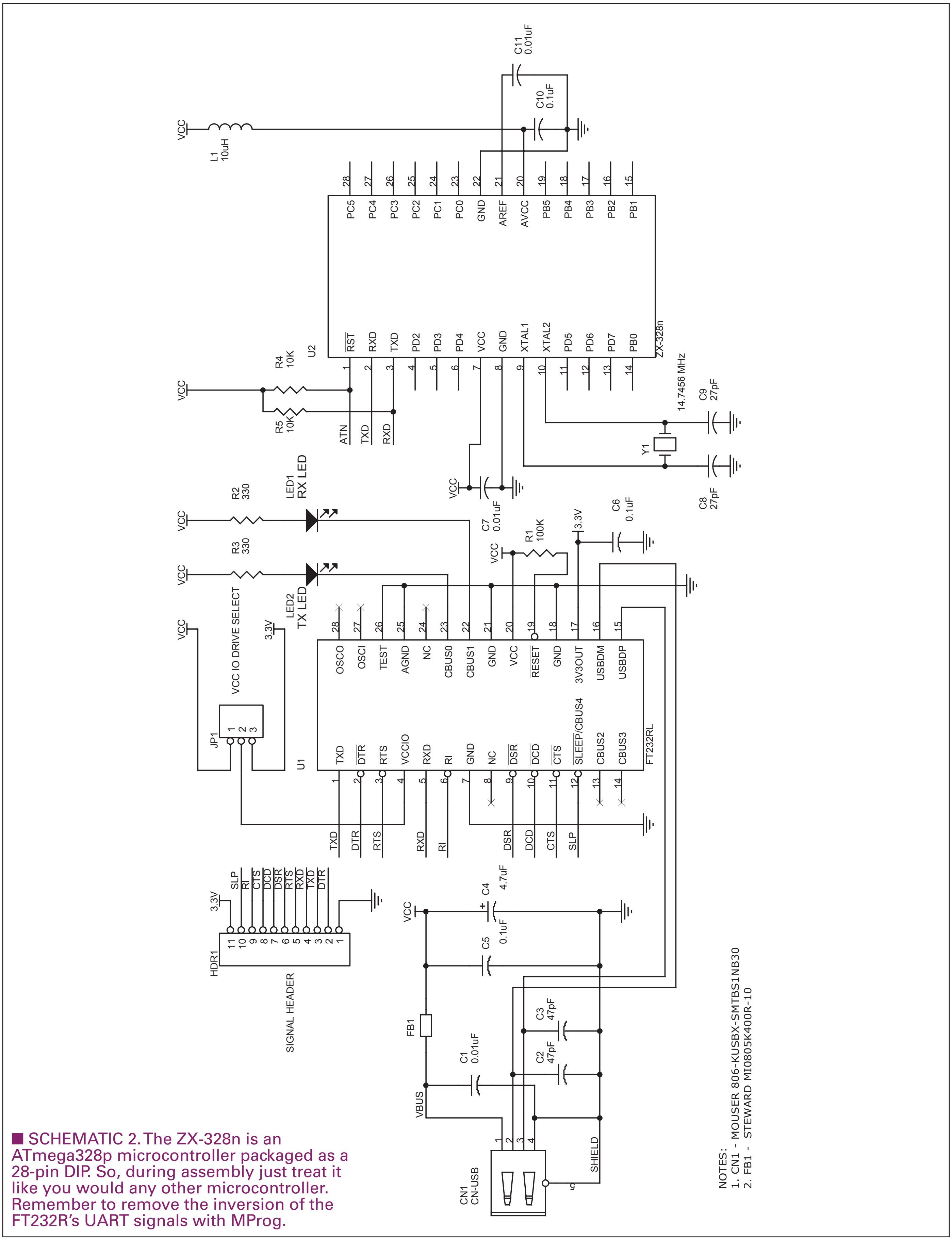
```
Const txPin as Byte = 0
Const rxPin as Byte = 0
```



■ SCREENSHOT 4. Seeing this message pop up in the Tera Term Pro window was gravy as the ZX-24a had already given me a visual "I'm working" cue.



■ SCREENSHOT 5. The ZBasic IDE is very intuitive. After putting the source code together, it was a simple F7 to compile and F5 to load and go.



■ SCHEMATIC 2. The ZX-328n is an ATmega328p microcontroller packaged as a 28-pin DIP. So, during assembly just treat it like you would any other microcontroller. Remember to remove the inversion of the FT232R's UART signals with MProg.

When using the AVR's UART, the transmit and receive pin definitions are defined as zero. While we're in a defining mood, let's put some aliases in place for the carriage return and line feed characters:

```
Const CR as Byte = &H0D
Const LF as Byte = &H0A
```

The next step in the serial communications process involves allocating a transmit and receive buffer. To do this, we first must define and allocate the buffer areas, which are called queues in ZBasic:

```
Dim rx_queue(1 to 24) as Byte
Dim tx_queue(1 to 24) as Byte
```

Okay, that should do it as far as definitions and allocations go. Now we can turn the ZBasic System Library calls loose on the ZX-24a hardware. All of the action takes place in the Main() subroutine code which I've captured in Screenshot 5. Here's the Main subroutine play by play:

1) The space we reserved for queues is initialized.
2) The AVR's UART is setup for 8 data bits, no parity and 1 Stop bit.
3) COM1 (the AVR UART) is opened at 19200 bps with the transmit and receive queues attached as buffers.

Our first telecommunications act is to place a carriage return and line feed in the transmit queue (tx_queue) for transmission. The results of the final post to the transmit queue can be seen in the Debug window area at the bottom of Screenshot 5.

A DESIGN CYCLE TRIFECTA

If your application is small and doesn't require the expanded resources of the ZX-24a, you can opt to lay down a ZX-328n on the ZBasic prototype board. The ZX-328n is actually an Atmel ATmega328p microcontroller loaded with a special ZBasic downloader.

All of the steps we took to interface the FT232R to the ZX-24a apply to the ZX-328n with the exception of the polarity of the FT232R's UART signals. The ZX-328n wants to see the UART signals noninverted. I show you how to hook up a ZX-328n to our ZBasic prototype board in Schematic 2. In the mean time, you can add three more devices to your Design Cycle. **NV**

■ *Fred Eady can be contacted via email at fred@edtp.com*

SOURCES

Elba Corporation — **www.zbasic.net**
ZX-24a; ZX-328n; ZBasic

FTDI — **www.ftdichip.com**
FT232R USB UART IC; MProg

ExpressPCB — **www.expresspcb.com**
Prototype Printed Circuit Board

IT'S SPRINGTIME AT RAMSEY!

Tri-Field Meter and "Ghost Detector"

- ✔ See electric, magnetic, and RF fields!
- ✔ Watch the magnetic fields of the earth!
- ✔ Sense different magnetic poles
- ✔ Detect RF transmitter fields
- ✔ Graphical LED display allows you to "see" the invisible fields

Recently seen on Ghost Whisperer!

Call it a Tri-Field Meter, an Electrical, Magnetic, and RF Detector, a Ghost Detector, or a Tricorder that even Mr. Spock would like, but what ever you call it, it works great to detect all three invisible fields!

The TFM3C has three separate field sensors that are user selectable to provide a really cool readout on two highly graphical LED bargraphs! Utilizing the latest technology, including Hall Effect sensors, you can walk around your house and actually "SEE" these fields around you! You will be amazed at what you see. How sensitive is it? Well, you can see the magnetic field of the earth... THAT'S sensitive!

The technical applications are endless. Use it to detect radiation from monitors and TV's, electrical discharges from appliances, RF emissions from unknown or hidden transmitters and RF sources, and a whole lot more! If your wondering whether your wireless project or even your cell phone is working, you can easily check for RF! A 3-position switch in the center allows you to select electric, magnetic, or RF fields. A front panel "zero adjust" allows you to set the sensors and displays to a known clean "starting point".

If the TFM3C looks familiar, it's probably because you saw it in use on the CBS show Ghost Whisperer! It was used throughout one episode (#78, 02-27-2009) to detect the presence of ghosts! The concept is simple, it is believed (by the believers!) that ghosts give off an electric field that can be detected with the appropriate equipment. Even Thomas Edison believed this as he made recordings of "voices from beyond". In the electric mode, the TFM3C's displays will wander away from zero even though there isn't a clear reason for it (not scientifically explainable, aka paranormal!). This would mean something has begun to give off an electric field. What it was in the Ghost Whisperer was a friendly ghost. What it will be in your house... who knows!

Makes a great teaching tool too! Learn all about the three types of fields and the sensors needed to detect them. Runs on 6VDC (4 AA batteries, not included).

TFM3C Tri-Field Meter Kit With Case $74.95

The High Tech Spotlight!

Hi-Res Elevation Sensor

- ✔ Elevation resolution to 1/3"!
- ✔ Pressure resolution to .0001kPa!
- ✔ 128x64 pixel graphical display!
- ✔ USB computer interface!
- ✔ Built-in Li-Ion battery!

The response to the UP24 was incredible! Customers from professional land surveyors, meteorologists, scientists, pilots and hikers to the curious hobbyist were overwhelmed with its sensitivity and accuracy. Reading realtime elevation to a third of an inch blew their minds! We made it even better...introducing the next generation UP24B!

First, for extended field use, we designed an internal lithium ion power cell and a state of the art power management system. Now you can charge it while it's connected to your USB connection, or use an external charger! Next we added a "MARK" feature. This allows storing a single data point reading when YOU want instead of blindly storing readings at the selected sample rate from an external switch (dry or electronic). Data is in comma delimited form for easy spreadsheet use.

Then we streamlined the controls to make a more compact profile. The rotary menu navigation dial has been replaced by contactless proximity buttons for more reliable operation! Just touch your way through the menus without any dials or switches! All in a handheld device that weighs less than 4oz! Visit www.ramseykits.com for details, there's just too much to fit here!

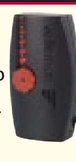
UP24B Elevation/Pressure Sens Kit $239.95
UP24BWT UP24B Factory Asmb $299.95

Pocket Audio Generator

A perfect test source for stereo line inputs on any amplifier or mixer. Provides 50Hz, 100Hz, 1kHz, 10kHz, & 20kHz tones, plus 32 bit digital pink noise. Great to help you identify cables or left/right reversals! Stereo RCA line level outputs. Uses 2xCR2025, not included.

K8065 Pocket Audio Generator Kit $32.95

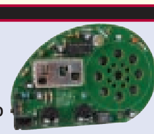
Pocket Vu Meter



Hand held audio level meter that fits in your pocket! Built-in mic picks up music and audio and displays it on an LED bargraph. Includes enclosure shown. Runs on one 3V Li-Ion button cell, not included. If you ever wanted an easy way to measure audio levels, this is it!

MK146 Pocket Vu Meter Kit $8.95

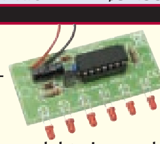
Portable FM Radio



Now you can build yourself a little FM radio receiver, learn about FM receivers, and have a neat little radio in the end! The RF front end is preassembled to make it simple. Receives the whole FM broadcast band 88-108 MHz. Runs on 12VDC.

MK118 FM Radio Receiver Kit $21.95

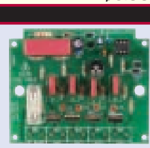
Mini LED Light Chaser



This little kit flashes six high intensity LEDs sequentially in order. Just like the K80302 to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.

MK173 Mini LED Light Chaser Kit $13.95

Running Light Controller



Controls and powers 4 incandescent lights so they appear to "travel" back and forth (Like the hood on KITT!). Great for the dance floor or promotional material attention getters, exhibits, or shows. Runs on 112-240VAC.

K8032 4-Channel Running Light Kit $38.95

High Power LED Driver

High power LED's have finally found their way into the hobbyist budget, but now you need a driver! This little board provides the accurate and constant current need to drive them. Delivers 350mA or 700mA at a constant current

K8071 High Power LED Driver Kit $14.95

Digital Voice Changer

This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.

MK171 Voice Changer Kit $14.95

Steam Engine & Whistle

Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.

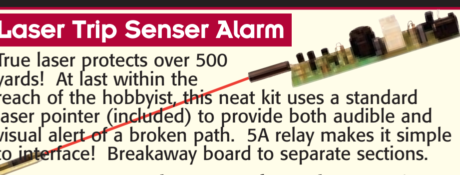
MK134 Steam Engine & Whistle Kit $11.95

Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Even includes adjustable sensitivity! Eats 2-8VAC or 9-12VDC, it's not fussy!

K2655 Electronic Watch Dog Kit $39.95

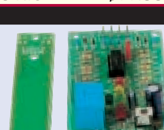
Laser Trip Senser Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 Laser Trip Sensor Alarm Kit $29.95

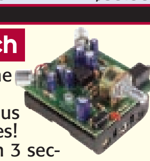
Liquid Level Controller



Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.

K2639 Liquid Level Controller Kit $23.95

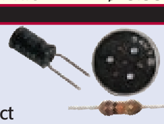
Call Code Activated Switch



What a concept... control things by the number of rings on your phone, and the number of rings is adjustable! Plus you can store up to 42 different codes! Activation can switch on a timer from 3 seconds to 56 hours. Relay output. Runs on 12VDC.

K2650 Call Code Activated Switch Kit $29.95

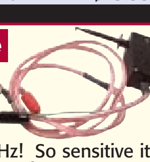
Electret Condenser Mic



This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1 Mini Electret Condenser Mic $3.95

Sniff-It RF Detector Probe



Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 Sniff-It RF Detector Probe Kit $27.95

Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

PR2 Broadband RF Preamp $69.95

Davis OBDII *CarChip Pro*

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226 CarChip Pro OBDII Monitor $99.95

Practice Guitar Amp & DI

Practice your guitar without driving your family or neighbors nuts! Works with any electric, acoustic-electric, or bass guitar. Plug your MP3 player into the aux input and practice to your favorite music! Drives standard headphones and also works as a great DI!

PGA1 Personal Practice Guitar Amp Kit $64.95

Passive Aircraft Monitor

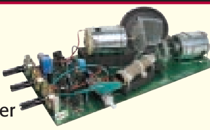
The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 Passive Aircraft Rcvr Kit $89.95

LED Blinky

Our #1 Mini-Kit for over 35 years! Alternately flashes two jumbo red LED's. Great for signs, name badges, model railroading, and more. Used throughout the world as the first learning kit for students young and old! Great solder practice kit. Runs on 3-15 VDC.

BL1 LED Blinky Kit $7.95

Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 Laser Light Show Kit $49.95

Electronic Siren

Exactly duplicates the upward and downward wail of a police siren. Switch closure produces upward wail, releasing it makes it return downward. Produces a loud 5W output, and will drive any speaker! Horn speakers sound the best! Runs on 6-12VDC.

SM3 Electronic Siren Kit $7.95

Universal Timer

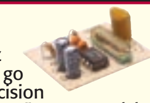
Build a time delay, keep something on for a preset time, provide clock pulses or provide an audio tone, all using the versatile 555 timer chip! Comes with circuit theory and a lots of application ideas and schematics to help you learn the 555 timer. 5-15VDC.

UT5 Universal Timer Kit $9.95

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 Voice Switch Kit $9.95

Tone Encoder/Decoder

Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Great for sub-audible "CTS" tone squelch encoders or decoders. Drives any low voltage load up to 100mA. Runs on 5-12 VDC.

TD1 Encoder/Decoder Kit $9.95

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit $19.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 Touch Switch Kit $9.95

Walking Electronic Bug

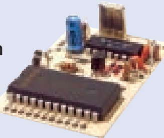
Built around a pair of subminiature cell phone motors, this bug wanders around looking for things to bump into! Sensors below his LED eyes sense proximity and make him turn away! Steer him with flashlights too! Runs on two "N" batteries.

WEB1 Walking Bug Kit $29.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1 Mad Blaster Warble Alarm Kit $9.95

DTMF Encoder Decoder

Decodes standard Touch Tones from telephones, radio, or any audio source. Detects and decodes any single digit and provides a closure to ground up to 20mA. Great for remote tone control Runs on 5VDC.

TT7 DTMF Encode/Decode Kit $24.95

Super Snoop Amplifier

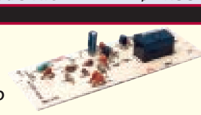
Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watt output drives any speaker for a great sound. Makes a great "big ear" microphone to listen to the "wildlife" both in the field and in the city! Runs on 6-15 VDC.

BN9 Super Snoop Amp Kit $9.95

Water Sensor Alarm

This little $7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump!). When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 Water Sensor Alarm Kit $6.95

RF Actuated Relay

Just what you need when adding a preamp or power amp in line with an antenna! Auto senses RF and closes an on-board DPDT relay that's good to UHF at 100W! Also great to protect expensive RF test equipment. Senses as low as 50mW!

RFS1 RF Actuated Relay Kit $19.95

HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13 HV Plasma Generator Kit $64.95

Air Blasting Ion Generator

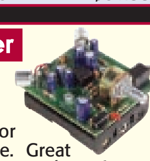
Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 Ion Generator Kit $64.95

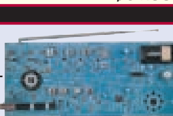
Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

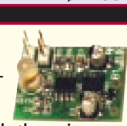
TS4 Tickle Stick Kit $12.95

Stereo Ear Super Amplifier

Ultra high gain amp boosts audio 50 times and it does it in stereo with its dual directional stereo microphones! Just plug in your standard earphone or headset and point towards the source. Great stereo separation besides! Runs on 3 AAA batteries.

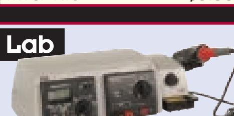
MK136 Stereo Ear Amplifier Kit $9.95

IC AM/FM Radio Lab

Learn all about AM/FM radio theory, IC theory, and end up with a high quality radio! Extensive step-by-step instructions guide you through theory, parts descriptions, and the hows and whys of IC design. Runs on a standard 9V battery.

AMFM108K AM/FM IC Radio Lab Kit $34.95

SMT Multi-Color Blinky

The ultimate blinky kit! The 8-pin microcontroller drives a very special RGB LED in 16 million color combinations! Uses PWM methods to generate any color with the micro, with switchable speed selection. SMT construction with extra parts when you lose them! 9V battery.

SBRGB1 SMT Multi-Color Blinky Kit $29.95

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

LAB1U 3-In1 Multifunction Solder Lab $129.95

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Q&A

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✔ Softening Up A Table Saw
- ✔ Returning Light To Christmas
- ✔ High Voltage Generation

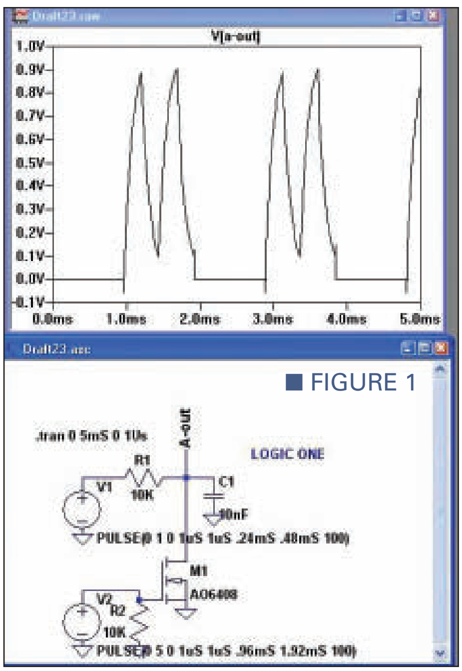
S.A.M.E. DECODING

Q I am looking for a way to extract solid TTL pulses from NWR S.A.M.E. encoded signals. I know the signal is AFSK, with 1562.5 Hz being logic zero and 2083.3 being logic one, and the data rate is 520.83 baud but it is 8N0, which is uncommon. I tried using two NE567 tone decoders tuned to the respective logic frequencies, and then used a comparator to get a single output signal. The output is not very stable though, and it seems like the 567s are either not fast enough, too high of bandwidth, or too low of bandwidth to handle the input audio — which I have tried adjusting all the way down to where the 567s just drop out or all the way up to get maximum bandwidth. Is there any way to get something clean in the way of a serial signal out of this or am I going to have to give something else a try? Maybe an XR-2211? And if so, a little help with it would go a long way! By the way, I will be feeding the serial data into a PIC16F648A programmed with PICBASIC PRO and it will operate at the odd baud setting, but I can't tell if the no stop bit thing will be a problem or not.

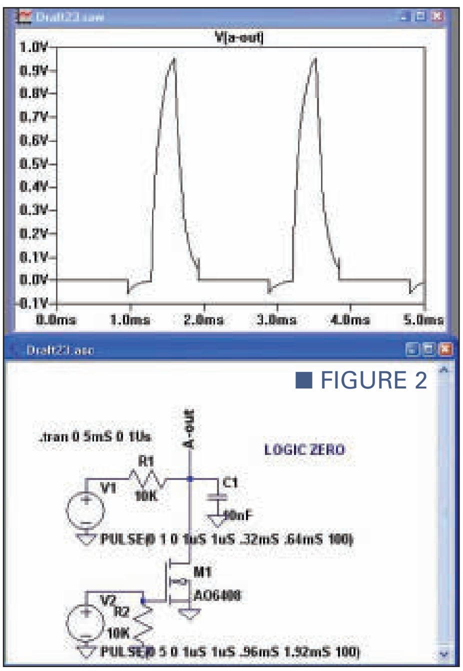
— Ryan

A For those not in the know, NWR stands for National Weather Radio and S.A.M.E. is Specific Area Message Encoding. The PLL should lock on the frequency with no problem and comparing the PLL output with the input should give the desired results; see Figures 1 and 2.

Note that the difference between the two frequencies is exactly the baud rate. That means you can tune the PLL to 520.83 Hz and be locked onto both frequencies. The logic one frequency is actually 2083.33. All your PIC micro has to do is decide if there are one or two pulses in the half period of the baud rate.



■ FIGURE 1



■ FIGURE 2

HIGH VOLTAGE SUPPLY DESIGN

Q I am writing in hopes of getting some direction to a problem that I have. I need a switching power supply that will supply extremely high voltage; in the 8,500 volt range. My experience is generally with linear power supplies under 30 volts and I don't know what direction to take. My question is: Can you recommend any books that could point me in the correct direction?

— Kyle Hvam

A I assume you want DC output; 8,500 volts is not difficult, the high voltage on television CRTs is around

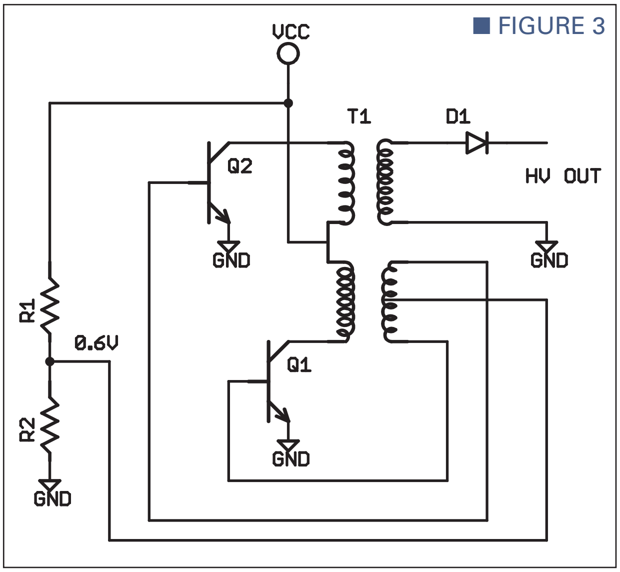
30,000 volts. The difficult part is supplying the power needed. If you need a one amp output, that is a problem. However, 1 mA is what I will assume you want.

I can think of a few ways to generate high voltage using a switching circuit:

1. Generate a square wave and increase the voltage with a transformer. You can find simple circuits like Figure 3, but those are no good because the transistor turn-off time is as long or longer than the turn-on time. During the switching time, both transistors are conducting which heats the transistor and burdens the power supply. The preferred circuit is explained in the SGSThompson application note on the SGS1525A integrated circuit (**www.datasheetcatalog.org/datasheet/SGSThomsonMicroelectronics/mXxyxw.pdf**).
2. Store energy in an inductor and dump it into a capacitor using a boost circuit. See **http://en.wikipedia.org/wiki/Boost_converter** for an explanation of how this works.
3. Use method A or B and a voltage multiplier circuit. See **http://en.wikipedia.org/wiki/Voltage_multiplier** for the explanation. This circuit is an example: **www.electronicsforu.com/efylinux/circuit/cir96.gif**.
4. Maxim application note 1109 illustrates a method of combining A and B to reduce stress on the switch. See **www.maxim-ic.com/appnotes.cfm/an_pk/1109/**.

Of course, the higher the voltage is that you start with, the easier it is to achieve the high voltage output because P_{in} – losses = P_{out}. To get 8,500 volts at 1 mA, the input with a 12 volt source is over 709 mA but the input with a 160 volt source is just over 53 mA. It is evident that the I^2R losses will be higher with the higher current.

One problem is that you can't find an 8,500 volt switching transistor (or if you could, it would not switch fast enough). So, you are stuck with a transformer, but then a multi turn transformer will have stray capacitance and will resonate at some frequency. You should not try to operate a transformer above its resonant frequency, so that is another limitation.



■ FIGURE 3

As an experiment, I simulated a boost circuit using an 8,500 µH coil which had 33 ohms resistance and resonated at 650 kHz. I simulated a 10:1 transformer by adding an 82 µH primary winding. The output was 1,400 volts with a 1 megohm load, so I added a second circuit (see Figure 4) and got 2,400 volts with a 260K load. Evidently, if you did this seven times you would reach 8,500 volts or more. You can regulate this voltage using feedback to pin 5 of the 555. I suggest a TL431 for the voltage reference and an optocoupler on the control pin.

There are several variations on this idea: You could have separate transistors driving each transformer, or you could have a single primary and multiple secondaries. The beauty of the circuit is that the transistor only needs a 500 volt rating and the secondary winding and the diode only need to have a 2 kV rating.

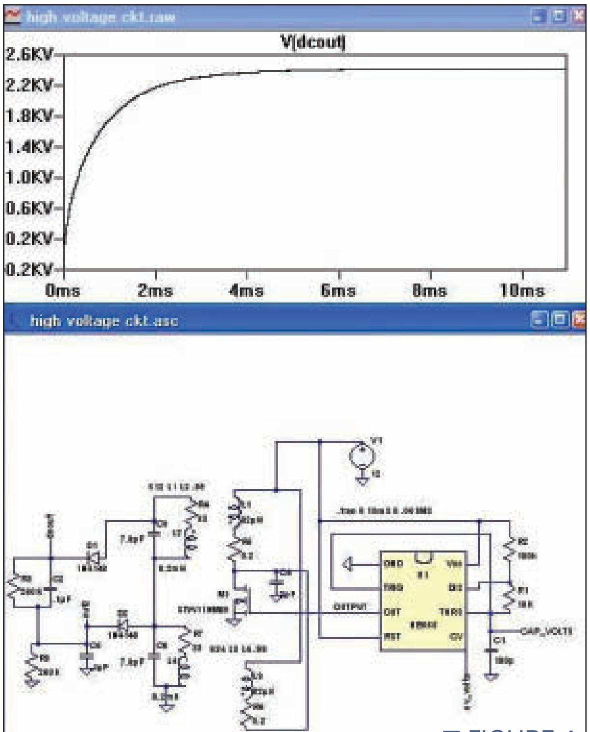
SOFT MOTOR START

Q I put this 5 hp motor on my table saw. It works like a miracle, but it jerks the arbor (saw blade) out of alignment. Is there a device or method to make this 230 volt, 3,450 rpm motor take more time — like maybe a whole second — to come up to speed?

— Chuck Larson

A The start winding on your motor draws a lot of current in order to give high torque to a heavy load, like an air compressor. Your application is essentially a no load start, so you don't need that high of current. I suggest that you change the starting capacitor to a smaller value, perhaps 1/4 as much as now being used.

PS: Feedback from Chuck — my guess of 1/4 was just right.



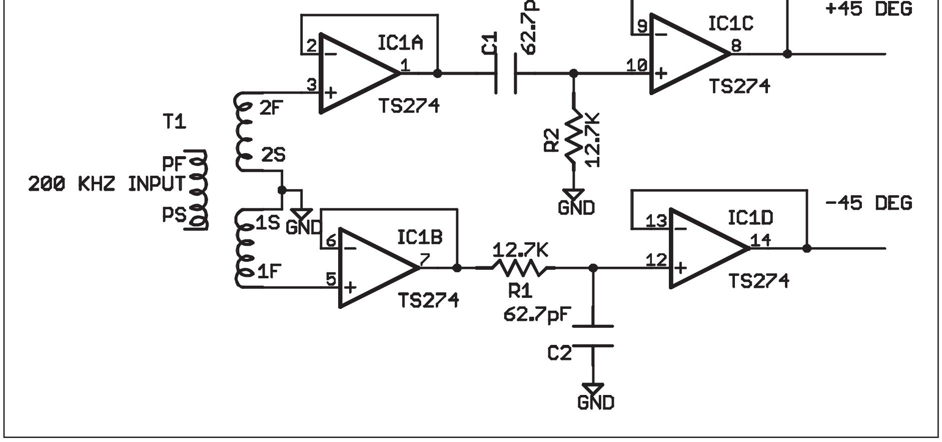
■ FIGURE 4

PHASE SHIFT NETWORK

Q I need a 90 degree phase shift that is +45 and -45, coming off a center tapped RF transformer. The transformer is running at 200 kHz and I need the RC values.

— Craig Kendrick Sellen

FIGURE 5



The phase shift is 45 degrees when the capacitive reactance equals the resistance. The choice of resistance is arbitrary; I initially chose 10K but changed to 12.7K to get a capacitor value close to standard (12.7K is a standard 1% value); see Figure 5. You can select the 62.7 pF cap from a bunch of 5% units, or trim to value or trim the 12.7K to compensate.

Since you will no doubt want to measure the phase angle, Figure 6 is a simple phase meter. The phase is read directly on a 200 mV meter, but it will not tell you if it is leading or lagging. To calibrate, first tie the two inputs together and adjust the zero output, then connect a dual D flip-flop in a divide by 4 Johnson counter circuit; see Figure 7. If you draw the timing diagram, you will see that the A and B outputs are exactly 90 degrees.

AT POWER SUPPLY PROBLEM

I have an AT style power supply that powers a single board computer. The problem is that the five volt rail isn't stabilizing quickly enough when I boot up the computer. The first time I power up, it doesn't boot but the second time it boots up fine. After doing some research, I found the CPU expects the five volt rail to stabilize in 300 ms or less. If the power isn't stable, the CPU won't boot. I believe that the capacitors in the power supply are already charged, so the second boot attempt allows the five volt rail to stabilize sooner. Is there a circuit that I can add (besides using a load resistor) that will let it boot up the first time?

— Jeff Miller

It is not likely that the five volt rail is coming up too slowly; more likely, it is overshooting and even ringing due to the light load. One possible fix is to add a thermistor in series with the 120 volt input to limit the inrush current. If you have a 300 watt supply, the input current is 2.5 amps nominal and Mouser part number 527-CL190 should work. Another possibility is to increase the capacitance on the five volt output. Doubling the filter capacity might do it. The last resort is to buy a better power supply.

TWO REQUESTS

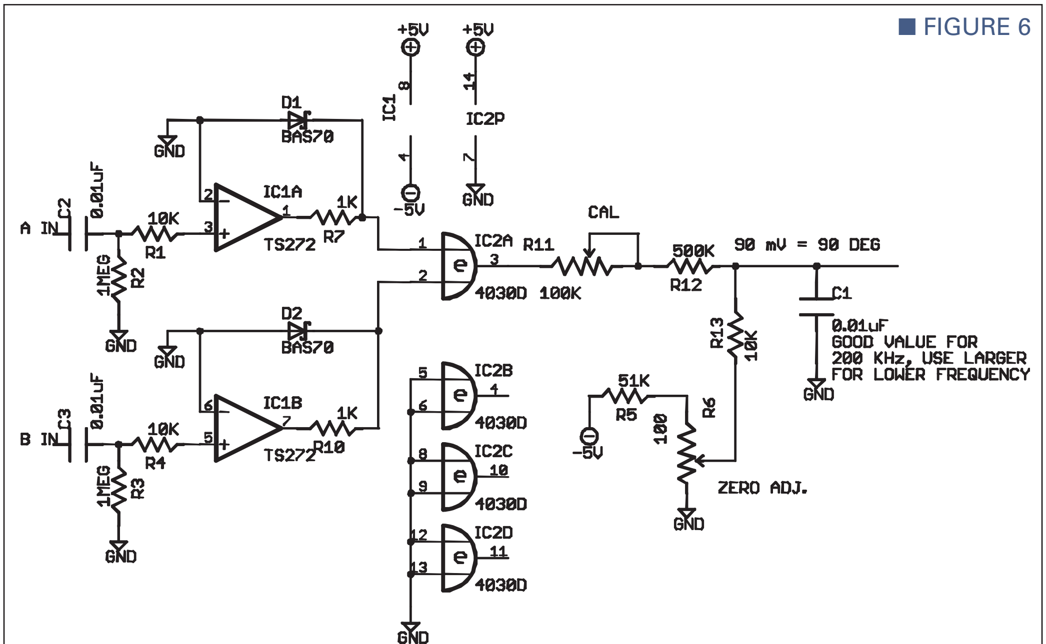
I have an industrial frequency counter using a logic-level, obsolete ICM7208 chip. I have need of a circuit to amplify a 50 millivolt RMS signal (1 to 10 MHz) to a logic level, five volt square wave. From there, I could divide by 10 or 100 should the 7208 not respond to the higher frequencies.

The second request is if there is a 14 or 16 pin DIP IC (pinout not important) that will perform the functions of an ICM7207A. While this IC is still available, it is cost-prohibitive. Thank you!

— Weldon Thorp

The amplifier you want must have a gain of 100 and a 10 MHz bandwidth. That is a 1 GHz gain bandwidth product for large signals. I don't know of any amplifier like that, and this

FIGURE 6



one doesn't do it either, but the output is 2V P/P at 10 MHz (1V to 3V), which I think will work. The schematic is shown in Figure 8. The KSC2757 is surface mount, SOT-23, and is available from Mouser.

The ICM7207A is a special-purpose IC; you are not going to find a replacement with the same functions. I found some on eBay for $42 each. That is probably cheaper than replacing the machine.

LED CHRISTMAS LIGHTS

Q Performing my pre-Christmas light check-out, I found one of my 115 volt AC 50 LED cords with only half of the 25 LEDs functioning. The cord has two sets of LEDs in series, along with a molded module. One of these modules had an open voltage condition. After dissecting the module, I found a 2.4K, one watt resistor and a circuit board with a copper device stamped with "GE15925" and "94V-0." I replaced the module with a 3K, 10 watt resistor and a 1N4001 diode in series with the 25 LEDs. This provided about 3.5 volts across each LED and they are about as bright as the working LEDs. However, my problem is the resistor gets warm. The other working module does not get warm. Any suggestions?

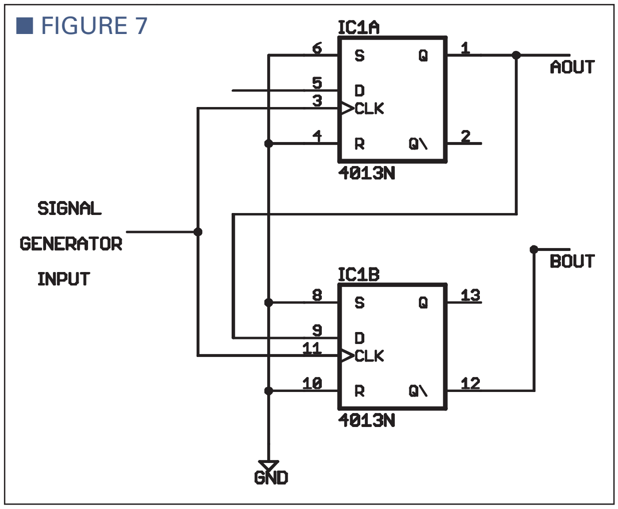
— Ray L. Heller

A I am assuming you meant to say that the two sets of LEDs were in parallel; it does not make sense otherwise. Since the LEDs drop 94 volts DC and are fed half waves from 162 VAC peak, the current is 23 mA peak and the drop across the resistor is 68 volts. The power dissipation is 1/2 of 1.5 watts which should make the 10 watt resistor warm, but not hot. If that is the case, you don't have a problem. I don't know how the module can drop the voltage without a capacitor in the circuit or how it could be cheaper than a 10 watt resistor.

AUDIO AMP HELP

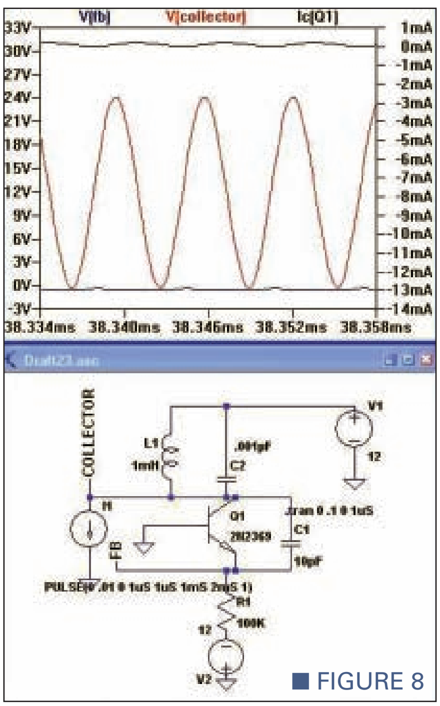
Q I recently purchased an MP3 player and use it every chance I get. I can listen to it with headphones and plug it into my car stereo, but I would really like to be able to listen to it without headphones when I am at home. I am an electronics hobbyist but must say I have very little knowledge on audio amplifier design. Is there a simple audio amp I can build that will drive two small speakers with the input it receives from the stereo headphone jack on my MP3? It would also be cool if the amp had a volume control and either a simple bass boost switch or tone control.

— David V. Martinez
Lubbock, TX

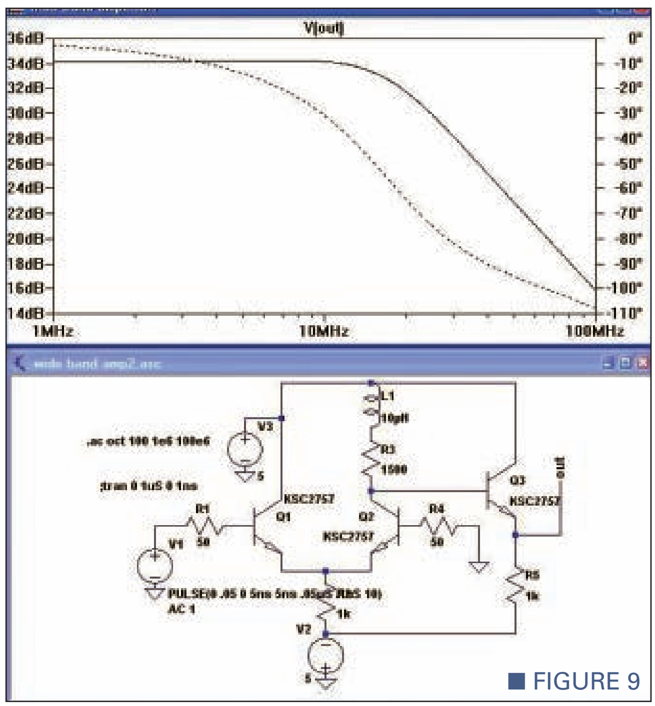


■ FIGURE 7

A The Velleman stereo audio amp kit — model K4003, 2 x 10W into eight ohms — will be a good way to start. The kit does not have any controls or power supply, so you will need a transformer and dual audio potentiometer (see Figure 9). For a tone control, I suggest 3.9 nF and a DPST switch in series as shown in Figure 9. You could use a 50K rheostat in place of the switch for more control. C1 and C2 knock down the high frequencies, so that is bass boost by default. You can download the K4003 manual at: **www.vellemanusa.com/downloads/0/illustrated/illustrated_assembly_manual_k4003_rev1.pdf**. **NV**



■ FIGURE 8



■ FIGURE 9

NEW PRODUCTS

- HARDWARE
- SOFTWARE
- GADGETS
- TOOLS

NEW DIGITAL RADIO KIT

Colorado Electronic Product Design (CEPD) introduces a digital radio kit consisting of three configurable printed circuit boards. The Digital Radio Kit (DRK) is intended to aid in the development and testing of algorithms and signal processing applications including:

- Digital radio, modulator/ demodulator development
- Software defined radio
- High speed data acquisition and signal processing
- Audio data acquisition and signal processing

The system combines a PCI card, an FPGA signal processing card, and a down converting digital radio card. All three cards have connectors allowing them to stack, forming a digital radio system. The kit will operate in standalone mode or the PCI card can be attached to a computer.

The standard configuration for the digital radio card is the 75 MHz to 150 MHz band. The digital radio card is capable of transmitting and receiving RF signals. Filters, low noise amplifiers, and mixers are socketed to simplify frequency changes. The card includes a frequency synthesizer LO and mixers for up and down conversion for transmitting and receiving.

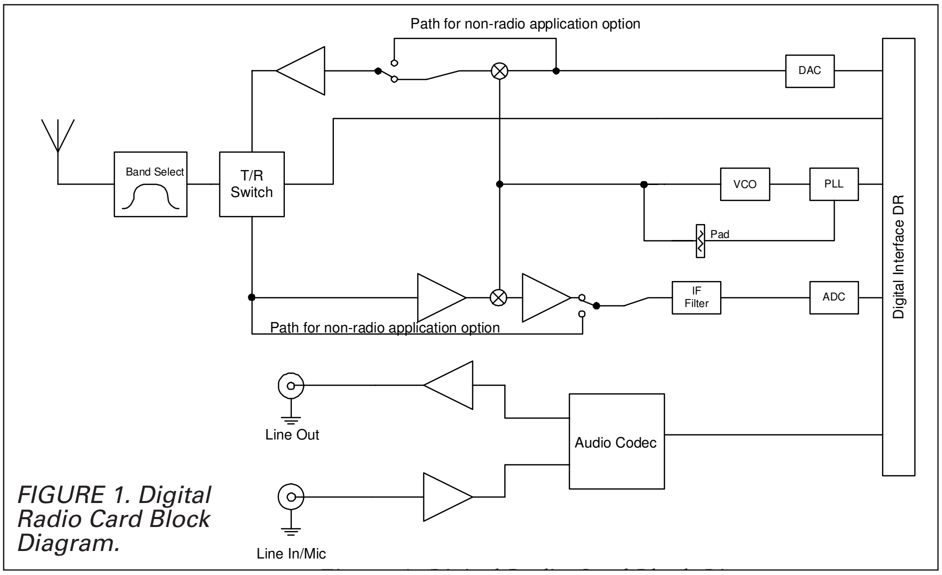


FIGURE 1. Digital Radio Card Block Diagram.

The card utilizes a 13-bit, 210 million samples per second (MSPS) analog-to-digital converter (ADC), a 14-bit, 400 MSPS digital-to-analog converter (DAC), and an audio codec.

The acquired signals are sampled and then digitally processed by the customizable FPGA card. Users may customize the FPGA to implement their own algorithms. The FPGA card comes with a JTAG programming connector and a configuration PROM to retain the FPGA settings.

The PCI card provides interfaces for the FPGA card to a computer PCI bus, RS-232, and user pushbuttons.

The DRK comes with a user's manual, reference design, and example FPGA code. The three card DRK is introductory priced at $1,599.

For more information, contact:
Colorado Electronic Product Design, Inc.
2845 Wilderness Place, Ste. 201
Boulder, CO 80301
Tel: **303-415-1112**
Fax: **303-415-1113**
Web: **www.cepd.com**

FIGURE 2. FPGA Card Block Diagram.

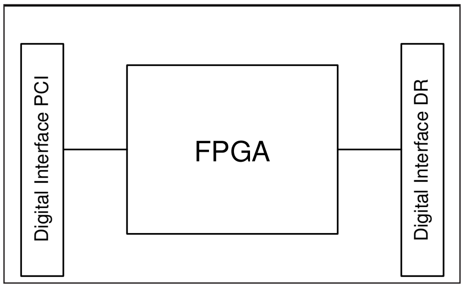
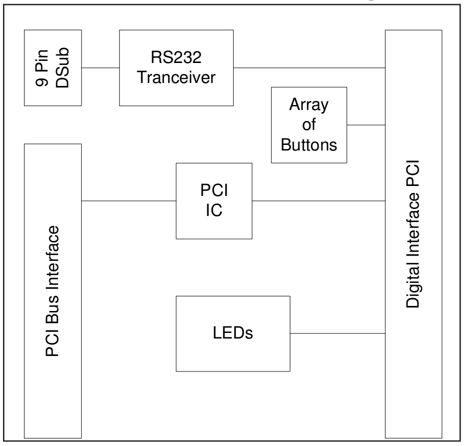


FIGURE 3. PCI Card Block Diagram.



SOLAR CONTROLLER MODEL 510

Electronic Control Concepts introduces the first product in its new line of alternative energy solutions. The Solar Controller Model 510 features ECC's own "intelligent charge" regulator designed to maximize efficiency and minimize the cost of implementing many solar solutions. The unit is proven to extend battery life by automatically preventing both

overcharge and deep discharge. The Model 510 is a user-friendly, flexible solar controller that makes it easy to implement a wide variety of solar applications that use photovoltaic panels, batteries, and a DC output or load. Applications include emergency power, DC lighting, pond aerator, water pumps, garden fountains, running a DC motor, and more.

In many applications, all that is necessary is to connect the recommended battery to the Model 510, hook up an appropriate solar panel, connect the DC load, and configure the Model 510 switches for the particular application. The Model 510 marries the battery, solar panel, and DC load so that they operate together seamlessly.

Each unit is fully customizable to meet the user's needs with several user-selected operating modes including duty cycle, deep cycle, and night mode. There are four photovoltaic/battery configurations (12, 24, 36, and 48 volt systems are available).

The Model 510 makes it easy to integrate photovoltaic panels, a battery, and a DC load into an operational system without the need to understand complex technical specifications.

For more information, contact:
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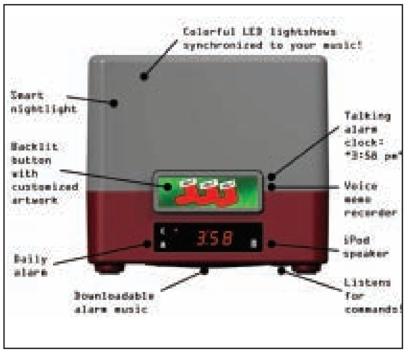

rCube's capabilities include recording voice memos and music to internal Flash memory and using either for the alarm. The MP3 speaker features colorful, synchronized LED light shows and a sound soother function. A 16-LED interactive nightlight includes multiple programs that respond to ambient light and sound. An integrated smart charger and optional backup battery allow for portable use and protection during power outages. rCube is available as a complete electronic kit, including a high-quality custom enclosure, for $39. A premium edition adds a scrolling, auto-dimming LED display with indoor temperature and an expanded Flash memory for $54. Both kits are available in multiple colors. An online web-based user forum is provided as an additional resource to kit builders to help answer any questions.

For more information, contact:
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Web: **www.rivalonline.com**

VIEWPORT SOFTWARE VERSION 4.1

Parallax is now selling ViewPort Software (Standard and Ultimate versions). ViewPort, developed by Hanno Sander at **MyDanceBot.com**, is the premier debugging environment for Parallax's eight-cog multiprocessing Propeller microcontroller. The tool combines an integrated debugger with powerful graphics that show you what's going on within the Propeller. Users can monitor variables over time with the built-in oscilloscope or change values while the Propeller is running. You can also solve hardware problems with the logic analyzer at sampling rates up to 80 Msps and add intelligence to programs with the fuzzy logic module or integrate computer vision using the OpenCV library.

The Standard version is low speed (up to 115 kbps) while the Ultimate version is high speed (up to 2 Mbps).

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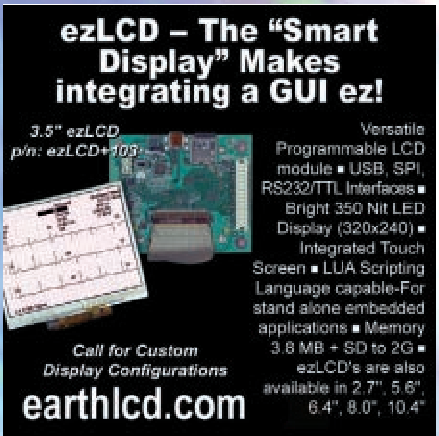
SHOWCASE



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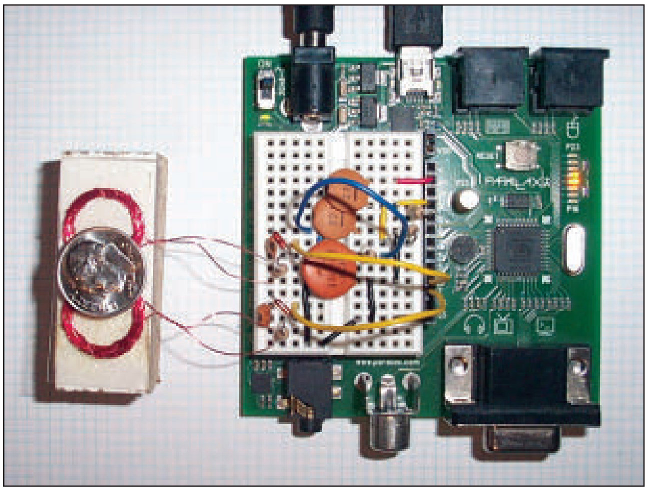
INDUCTIVE PROXIMITY SENSORS

PART 2

BY BEAU SCHWABE

Last month, we covered the "Series Resonant" circuit, coil construction, and I promised to explain why there were two different operation modes for our demo. So, here goes ...

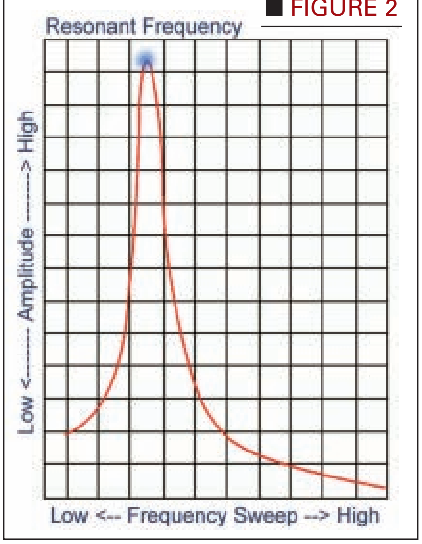
■ FIGURE 1. The prototype board with a dime to shift the resonant frequency of the coil.



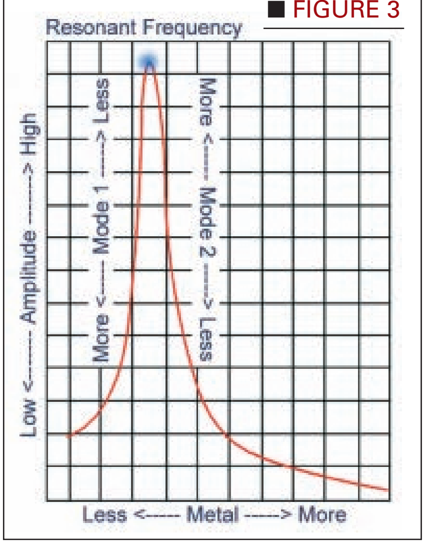
At the beginning of the program, there is a small calibration routine that determines what the resonant frequency of the coil is. This is done by sweeping a frequency and monitoring the amplitude. For each swept frequency, the amplitude is measured and compared against previous amplitude readings. The frequency with the highest amplitude represents the resonant frequency of the coil and capacitor combination (see **Figure 2**).

Keep in mind that adding metal to the presence of a coil will increase the resonant frequency. Likewise, removing metal from the presence of a coil will decrease the resonant frequency. In operation Mode 1, the coil is calibrated without metal. This causes the frequency to increase (shift to the right in the graph) when metal is introduced to the coil. The circuit then detects the amplitude of the signal from the left side of the resonant calibration frequency that was obtained without metal present. In operation Mode 2, the coil is calibrated with metal in the presence of the coil. This causes the frequency to decrease (shift to the left in the graph) when metal is removed from the coil. In this case, the circuit detects the amplitude of the signal from the right side of the resonant calibration frequency that was obtained with the presence of metal (see **Figure 3**).

■ FIGURE 2



■ FIGURE 3



Making A Differential Sensor

In the next circuit, we will be adding a second coil plus a capacitor, resistor, and a diode to make a differential sensor. Don't worry, the circuit used here will still be the same as the one used in Part 1. The benefit of differential sensing is that it will naturally be immune to any temperature variations and other electrical noise that could enter the system. Secondly, it is an easy way to make a sensor that can detect absolute positioning as we will demonstrate.

The layout of the two coils isn't terribly critical; depending on the application, they could be side by side (the way I have done it ... see **Figure 4**) or they could be parallel to one another where a metal object moves

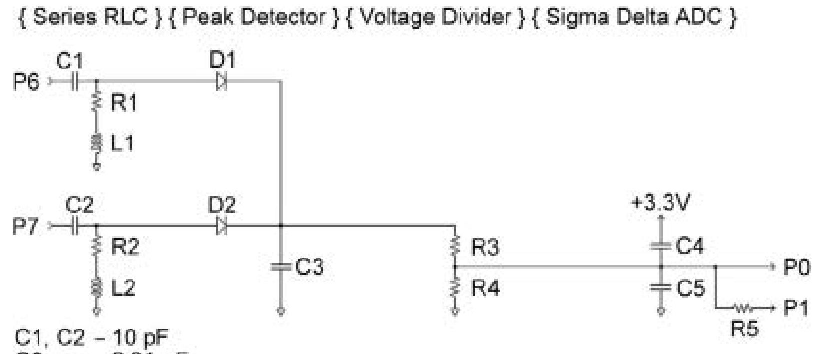
in-between them. In my setup, I just used a piece of scrap wood to position the coils using a small dot of super glue. I used a clear scrap piece of packaging plastic over the top of the coils to create a smooth sliding surface. I didn't want the plastic to "fog" from using glue, so I applied a small amount of clear nail polish just to hold the plastic in place.

In the software portion of this design, we are going to set up the calibration a little differently. We basically will be running in Mode 2 where metal is present but only partially covering half of each coil (refer again to **Figure 1**). Because of this, we want to find a frequency somewhere on the right side of the resonant peak. To determine this frequency, we'll use the same sweeping method that we used before to find the resonant frequency. During the process of determining the resonant frequency, we found the maximum voltage which we can also use to determine a second point on the graph. If we continue to sweep the frequency until we reach half of the maximum voltage (found during the peak detection), we now have a new point on the graph that we can use for detecting not only the removal of metal near the coil but also the addition of metal near the coil (see **Figure 5**).

We could have set this up using the left side of the peak, but the response would be inverted. For example, if you introduced more metal, the returned value from the ADC would go down. The way it is now seems more intuitive and the returned value from the ADC goes up when additional metal is introduced to the coil. Using this technique and combining it with a second coil to create a complementary or differential relationship creates a sensor that can resolve an absolute position.

Now What?

Connect the components as shown and run the program with a piece of metal placed halfway between each coil. I used a dime since a quarter seemed too big. If



C1, C2 – 10 pF
C3 – 0.01 µF
C4, C5 – 220 pF
D1, D2 – 1N914
L1, L2 – Sense Coil (25 Turns 30 Gauge air-core style 14.5 mm diameter form)
R1, R2 – 100Ω
R3, R5 – 1Meg
R4 – 220K

■ SCHEMATIC

Software

The code for this demo "Inductive Proximity Sensor Part 2.spin" can be downloaded from the Propeller Object Exchange at **www.obex.parallax.com**. Here are some excerpts:

In the CON section this code tells the Propeller what Crystal frequency we are using, and that we want to use the PLL to multiply the Crystal frequency by 16.

```
_XINFREQ = 5_000_000        'Propeller Processor Crystal value (5MHz)
_CLKMODE = XTAL1 + PLL16X   'Set PLL value to X16 to get an 80MHz (5MHz x 16 = 80MHz) clock
```

In the CON section this code configures what pins will be used with our hardware.

```
  SensePin = 0               'ADC INPUT pin
  DrivePin = 1               'ADC OUTPUT pin
  FPin1    = 6               'Frequency Synthesizer OUTPUT pin 1
  FPin2    = 7               'Frequency Synthesizer OUTPUT pin 2
```

In the CON section this code configures the Start Frequency, Stop Frequency, and Sweep Step required for the auto calibration routine.

```
  StartFrequency = 8_00_000  'Start Frequency to Sweep ... 500 kHz to 128 MHz
  StopFrequency = 10_000_000 'Stop Frequency to Sweep ... 500 kHz to 128 MHz
  SweepStep = 20_000         'Sweep increment used in auto calibration
```

In the VAR section, define some variables that we will be using.

```
long                  ADCmax,VMax1,VMax2,Fmax1,Fmax2,Scan1,Scan2,Sample
```

Auto calibration main loop

```
    cognew(@asm_ADC, @Sample)                  ' launch Sigma Delta ADC ; uses CTRA

    Fmax1 := Calibrate_Coil(FPin1)             ' Initiate calibration for coil 1
    Vmax1 := ADCmax                            ' Maximum voltage level at peak resonance
    Fmax2 := Calibrate_Coil(FPin2)             ' Initiate calibration for coil 2
    Vmax2 := ADCmax                            ' Maximum voltage level at peak resonance
--------------------------------------------------------------------------------------------
PUB Calibrate_Coil(Pin)|Temp, Frequency

''Calibrate Coil
    Result~                                    ' Clear Result
    ADCmax~                                    ' Clear ADCmax
    repeat Frequency from StartFrequency to StopFrequency step SweepStep 'Sweep frequency

      Synth(Pin, Frequency)                    ' set oscillator ; uses CTRB
      waitcnt(cnt+clkfreq>>6 )                 ' Delay ; Allow ADC to settle for 1/64th sec

      Temp := 0                                ' Average five ADC Samples
      repeat 5
        Temp += Sample
      Temp /= 5

      if Temp => ADCmax                        ' Detect 'peak' voltage value from ADC
         ADCmax := Temp                        ' this will be the resonant frequency
         Result := Frequency                   ' of the RLC circuit
```

```
'' Determine "Mode 2" mid-point voltage

    repeat Frequency from Result to StopFrequency step SweepStep          'Sweep frequency

      Synth(Pin, Frequency)                                               ' set oscillator ; uses CTRB
      waitcnt(cnt+clkfreq>>5 )                                            ' Delay ; Allow ADC to settle
                                                                          ' 1/32th of a second

      Temp := 0
      repeat 5                                                            ' Average five ADC Samples
        Temp += Sample
      Temp /= 5

      if (Temp*2) =< ADCmax                                               ' Check mid-point voltage level for Mode 2
         Result := Frequency
         quit
```

DEMO program main loop

```
    dira[16..23] ~~                                                       ' Set I/O direction of LED's to output

    repeat

      Synth(FPin1, Fmax1)                                                 ' Set the oscillator to the resonant frequency
      waitcnt(cnt+clkfreq>>6 )                                            ' Delay ; Allow ADC to settle for 1/64th of a second
      Scan1 := Sample                                                     ' Get ADC Sample

      Synth(FPin2, Fmax2)                                                 ' Set the oscillator to the resonant frequency
      waitcnt(cnt+clkfreq>>6 )                                            ' Delay ; Allow ADC to settle for 1/64th of a second
      Scan2 := Sample                                                     ' Get ADC Sample

      Scan1 := ((Scan1 * 8)/Vmax1)                                        ' Scale ADC value to range from 0 to 8
      Scan2 := 8-((Scan2 * 8)/Vmax2)                                      ' Scale ADC value to range from 0 to 8, but invert output

      outa[23..16] := |< ((Scan1 + Scan2)/2)                              ' Turn on 1 of 8 LED's based on differential ADC value
```

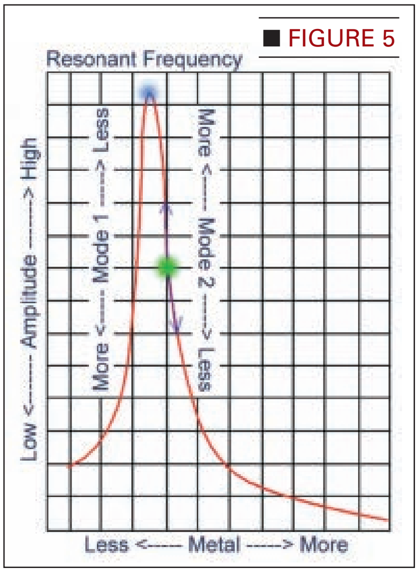
Subroutines to set synthesizer frequency

```
PUB Synth(_Pin, Freq) | s, d, ctr, frq
    Freq := Freq #> 500_000 <# 128_000_000                                'limit frequency range

    ctr := constant(%00010 << 26)                                         '..set PLL mode
    d := >|((Freq - 1) / 1_000_000)                                       'determine PLLDIV
    s := 4 - d                                                            'determine shift
    ctr |= d << 23                                                        'set PLLDIV

    FRQB := fraction(Freq, CLKFREQ, s)                                    'Compute FRQB value
    CTRB := ctr | _Pin                                                    'set PINA to complete CTRB value
    DIRA[_Pin]~~                                                          'make pin output

PRI fraction(a, b, shift) : f
    if shift > 0                                                          'if shift, pre-shift a or b left
      a <<= shift                                                         'to maintain significant bits while
    if shift < 0                                                          'insuring proper result
      b <<= -shift
    repeat 32                                                             'perform long division of a/b
      f <<= 1
      if a => b
        a -= b
        f++
      a <<= 1
```

Assembly subroutine to start Sigma Delta ADC

```
DAT
asm_ADC         org
                or        dira,DrivePinMask                               'make DrivePin an output

                movs      ctra,#SensePin
                movd      ctra,#DrivePin
                movi      ctra,#%01001_000                                'POS W/FEEDBACK mode for CTRA
                mov       frqa,#1

                mov       count,cnt                                       'prepare for WAITCNT loop
                add       count,cycles
:loop
                mov       phsa, #0                                        'clear PHSA
                waitcnt   count,cycles                                    'wait for next CNT value
                mov       _sample,phsa                                    'move PHSA into sample
                wrlong    _sample,par                                     'write sample back to Spin variable "sample"
                jmp       #:loop                                          'wait for next sample

cycles          long      3300                                            'VDD Voltage level (mV)
DrivePinMask    long      |< DrivePin                                     'output mask
count           long      0
_sample         long      0
```

■ FIGURE 4



■ FIGURE 5

PARTS LIST

ITEM	DESCRIPTION	SUPPLIER/PART #
❑ Platform	Propeller demo board	Parallax/32100
❑ C1,C2	10 pF capacitor	Digi-Key/478-3160-ND
❑ C3	0.01 µF capacitor	Digi-Key/478-3178-ND
❑ C4, C5	220 pF capacitor	Digi-Key/478-3168-ND
❑ D1, D2	1N914 diode	Digi-Key/1N914ACT-ND
❑ L1, L2	30 gauge enameled copper wire	RadioShack/278-1345
❑ RI, R2	100Ω resistor	Digi-Key/OD101JE-ND
❑ R3, R5	1M Ω resistor	Digi-Key/OD105JE-ND
❑ R4	220K Ω resistor	Digi-Key/OD224JE-ND

the piece of metal is too large, the coils may saturate and not respond ideally. The Propeller should take about six seconds to load the program and calibrate the coils. After it has properly calibrated itself, you should see the center LED light up. (Since there are only eight LEDs, there really isn't a center — it will actually be LED number 4 or LED number 5 that is lit.)

Next, try moving the coin or piece of metal slowly back and forth and observe the LEDs. They should follow the same direction you are moving the metal in. In my experiments, I observed a full scale LED range when only moving the dime about 1/8th of an inch.

Feel free to come up with your own enhancements to this project. Think of ways that you could modify the hardware and software so that you could use three or even four coils to create a joystick type of input device, for example. Whatever you do, be sure to visit the Parallax forums (**http://forums.parallax.com/forums**) and share your experiences. We'd love to "detect" your presence there! **NV**

article continues on next page

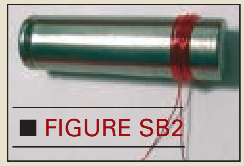
Coil Construction

Just in case you missed Part 1, here is what you will need to know to make the coils for this month's project.

■ FIGURE SB1. The materials you will need.

The materials you will need include:

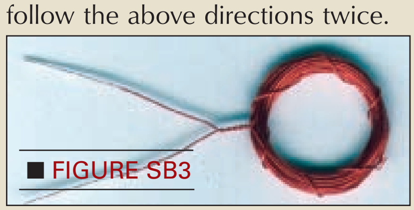
- 96 inches of 30 gauge enameled copper wire (48 inches required for each coil). (RadioShack sells this as the "red" spool in their three-pack of magnet wire).
- 100 grit sandpaper
- 14.5 mm coil form that you can easily slide the finished coil off of (I used a rechargeable AA battery with the label removed).



■ FIGURE SB2

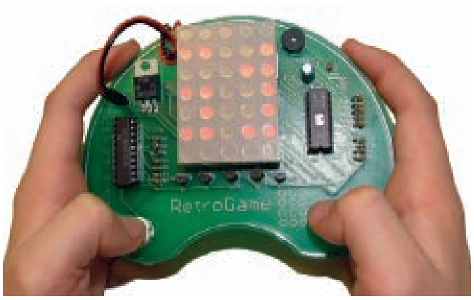
With 48 inches of enameled copper wire, wind 25 turns over the coil form leaving about an inch of lead length from the coil. Twist both ends together with about five twists (**Figure SB2**). Slide the coil off of the coil form. To prevent the coil from unwinding, cut a 3.5 inch scrap piece of enameled wire from the spool. Wind the scrap piece of wire in a toroid fashion around the coil and twist the ends together, trimming off any excess wire you may have when you are done (**Figure SB3**). It should only take five or six toroid loops with the scrap piece of wire to secure a coil of this size.

To remove the enamel from the ends of the coil wire, start by cutting a small piece of 100 grit sandpaper about 1.5 inches by 1.5 inches. Fold the sandpaper in half with the sand facing the inside. Place the end of the enameled wire inside the folded sand paper, lightly pinch the wire between your thumb and forefinger, and gently pull it along the wire to its end. After a few passes, you will see the red enamel come off and the copper wire underneath will be revealed. Work around the wire until there is a bright copper area at the end of it, about a half inch in length. To construct two coils, you will need to follow the above directions twice.



■ FIGURE SB3

RETRO GAME



So, my wife volunteered me for "Science Day" at my son's elementary school — an annual half day program where moms and dads taught mini-courses on everything from rocketry to zoology to chemistry. But what could I teach the kids? No sooner did the thought cross my mind, did I get the answer: build a video game!

NOTE – in the source code on the RetroGame web-site, the duration table in `music.asm` is incorrect. The note durations are wrong. The table should read as follows. It isn't fatal as is, though.

```
MusicClickTable:
      retlw d'3'         ; quarter
      retlw d'6'         ; half
      retlw d'9'         ; dotted half
      retlw d'12'        ; whole
```

BY ERIC ROTHFUS

Thus, the "RetroGame" was born. The RetroGame is a simple hand-held video game that was designed to be assembled by third to fifth graders during a 45 minute Science Day period. The game physically consists of a PCB (printed circuit board) with a 5x7 LED matrix display, two pushbuttons, and surrounding control and power electronics. The games were fully soldered by the time the kids got them, but the main parts including the processor and display were socketed, so the kids would have to "assemble" the games themselves.

I created two games for the RetroGame, each as a separate firmware load for the processor PIC:

RetroRover 2006

In this game, your "moon rover" (a flashing LED) has to make its way through rough terrain which constantly approaches from above. The buttons allow you to move from side to side.

Retris 2007

This is a mini Tetris where small pieces can be moved from side to side, but not rotated. This proved to be the most popular game.

I would have created a few more games, but ran out of time. The software architecture lends itself to (relatively) easy game creation, fortunately.

Building the RetroGame

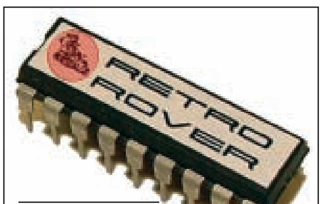
My first task was to do the basic design of the game, and then try to procure the cheapest parts I could, which would then drive the final design of the circuit and layout of the PCB — though I already knew that I wanted the PCB to look like a retro video-game controller. After finding the basic parts, I went on a search for a cheap processor.

I decided on a PIC 16C620. It was small with 18 pins, and had a useful amount of memory. Most importantly, I could get a bunch of them cheap! Since the game is simple, very few I/O pins were necessary. In fact, one remained unused ... which never happens in any of my projects.

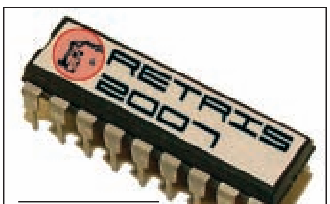
I wasn't sure how much memory I needed at first, so I started with the 620, but quickly realized that movng up to a 622A would be necessary. They are pin-compatible, so it was an easy move.

The RetroGame circuit itself is very simple, and consists of the following basic sections:

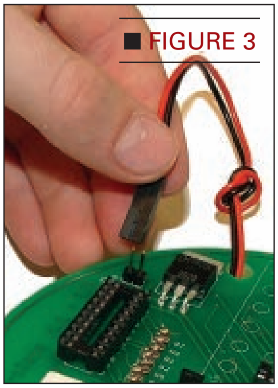
- **Power:** As my concerns were more with cost than efficiency, the power section of the circuit uses a 7805 five volt regulator that converts the nine volts from the battery. The regulator is old technology that you can get very cheaply, but it uselessly dissipates a bunch of heat when in use. You should notice fairly quickly that there is NO power switch for the RetroGame. To turn it on, you plug in the battery connector. Eliminating the switch saved some money and the kids loved the hands-on feel of plugging in the power.
- **Input:** Two momentary push buttons pull two input pins of the PIC controller to ground when pressed. Otherwise, pull-up resistors (R9, R10) pull them to +5V. These pushbuttons are the only user input for the game. I used cheap switches which "bounce" quite a bit. The software deals with this issue. I briefly considered adding a third pushbutton (because I already knew I wanted to create Retris and wanted rotation) but abandoned the idea in favor of simplicity.
- **Processor:** The processor section consists only of the PIC 16C622A (the generic 16C620 is shown in the schematic). Note that the internal oscillator is being



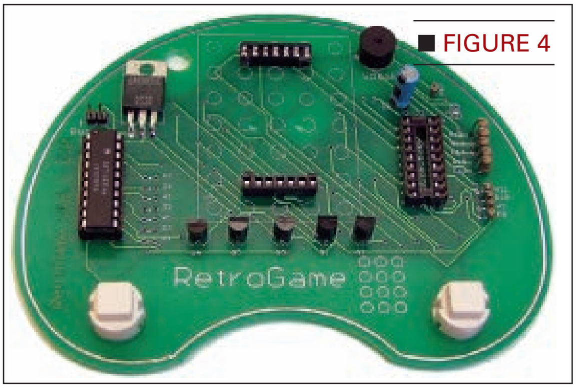
■ FIGURE 1



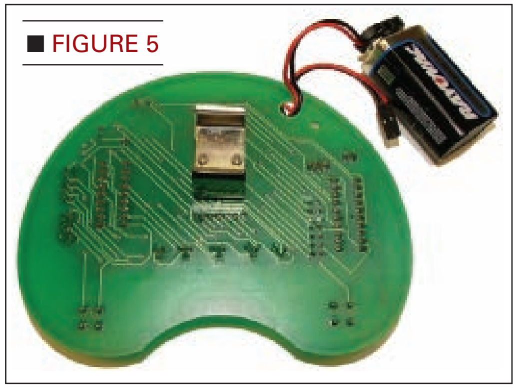
■ FIGURE 2



■ FIGURE 3



■ FIGURE 4



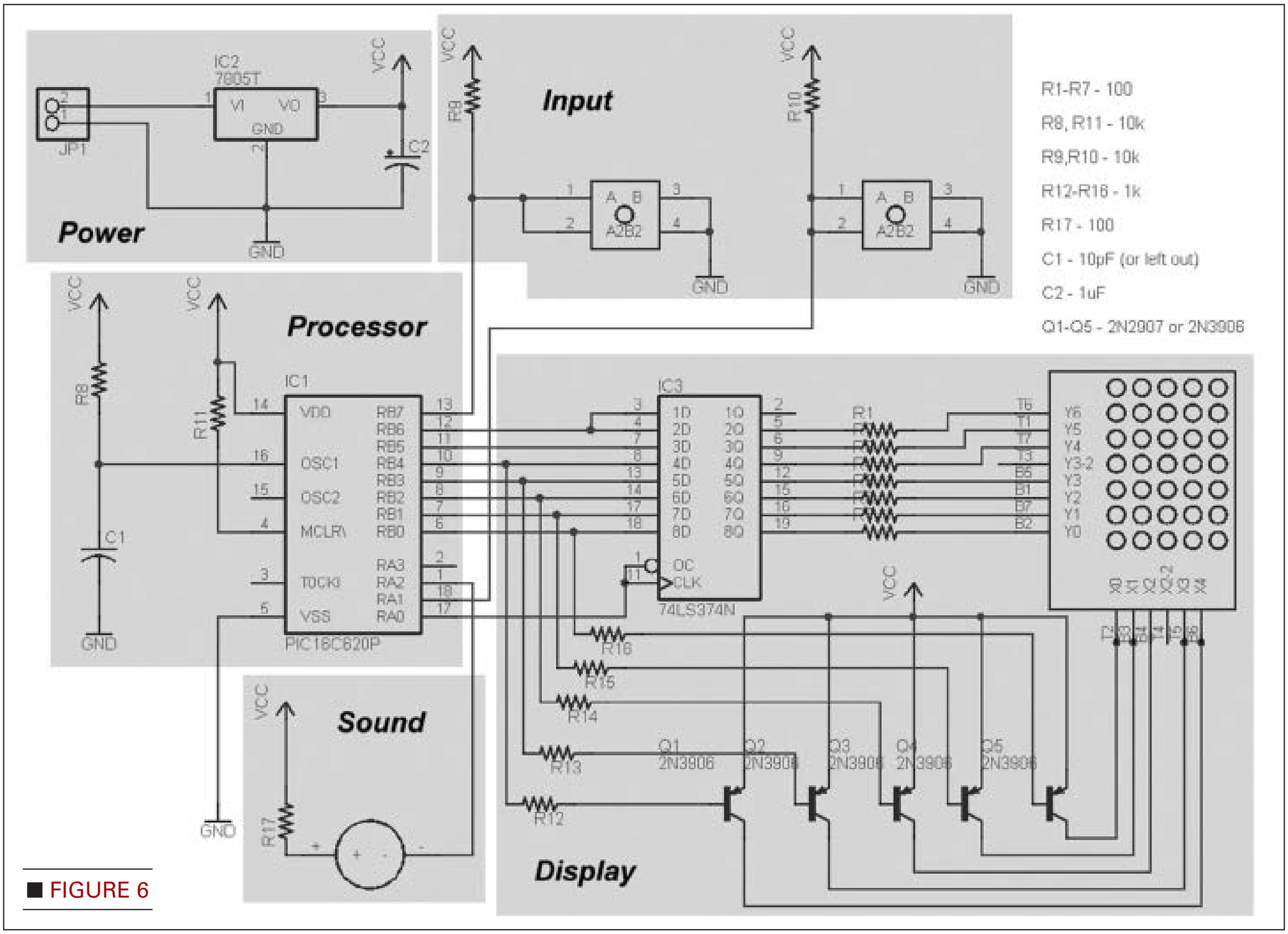
■ FIGURE 5

used for the clock. Since this is just a video game, the precision of a crystal-controlled clock is unnecessary. Note, too, that in the schematic that C1 can be left out. I left it out for the kids; you'll see why later.

- **Sound:** The sound part of the circuit consists primarily of a little piezo-electric speaker that is connected directly to one of the processor I/O lines. Sound is produced by bit-banging the speaker. (See the section on RetroGame Sound.)
- **Display:** The most complicated part of the circuit is the LED display section. It consists of the 5x7 LED matrix along with a data latch and transistor column drivers. The LEDs on the matrix are rapidly flashed, as described in the section on RetroGame Display.

The circuit was originally created on a breadboard, which allowed experimentation mostly on the display section. It also allowed me to begin software development while I waited for the PCBs to be manufactured.

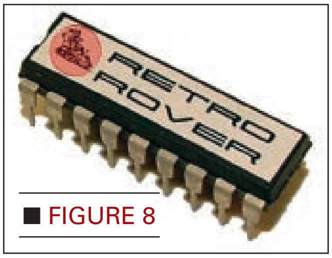
Arguably, the coolest part of the RetroGame is that you play it while holding on to the PCB itself which is shaped like an old video game controller. The silver strip running around the circumference of the PCB is just for looks.



■ FIGURE 6

Creation of the PCB was relatively simple. I used the Eagle editor for a simple two-sided through-hole design with parts on one side only — almost. The battery holder is attached to the back of the RetroGame with two screws and nuts.

■ FIGURE 7



■ FIGURE 8

Although it's obvious that no components could be soldered where the metal battery holder was placed, what wasn't obvious to me at first is that the vias from top to bottom needed to be kept away from the holder area too. I could count on the PCB solder mask to prevent short circuits due to the battery clip contacting traces, but I couldn't count on it to protect the vias. So, I set up the battery holder area in the design to exclude vias ... simple.

Populating the PCB was easy with the through-hole design. The only interesting detail is that the major components were to be socketed, allowing the kids to be involved in the assembly. The display driver and the PIC would have normal sockets. The LED matrix, however, needed something special — two single row, seven-pin sockets. If you haven't looked lately, those things are expensive. Instead, I simply cut a 14-pin socket in half.

The socket for the display also served to keep the display away from the screws that attached the battery holder to the back of the PCB.

You may notice that there is no heatsink on the 7805. There probably should be, but the circuit doesn't draw too much power, so in practice it doesn't get too hot. To mitigate the potential for a kid to burn a finger, I mounted the 7805 flat against the PCB.

Science Day Cometh!

The RetroGame was done in plenty of time for Science Day, although I still had quite a bit of work to do to get ready for the kids. One important issue that I wanted to prevent was potential incorrect orientation of the ICs. The display wasn't a problem in that it can be mounted in either orientation.

To solve the PIC orientation problem, I simply used little colored stickers. The PIC had a red dot on it (which doubled as the game label) and the 74LS374 had a blue dot on it. The dots were strategically placed on one end of each chip, and a matching dot was placed on the PCB itself. The kids just had to line them up!

Science Day went great! We had 100% success rate with 65 third through fifth graders assembling and playing their own video game. There were a few problems (like bent pins) and a couple resultant messed up sockets, but spare parts solved the problems.

Remember that I didn't recommend installing C1 in the final RetroGame? C1 is the capacitor that helps set the frequency for the internal PIC oscillator. By not installing it, I found that you could easily affect the speed of the clock with your finger. In fact, you could slow the game down dramatically to the point where you could see the flashing of the display, and the game itself would operate so slowly you could get yourself out of problems. I was somewhat surprised by how quickly the kids were able to take advantage of this little trick! One student even figured out how to lay his finger on the underside of the board when he needed it.

RetroGame Display

The display for the RetroGame is a row cathode, column anode LED matrix. At first glance, you may ask yourself, how do you individually drive 35 different LEDs with only 12 signal lines? Fine question.

As the name implies, the display is a "matrix" of LEDs. The cathodes (-) of each LED in a given row are connected together, while the anodes (+) in a given column are connected together. To turn on an LED, you apply power and ground to a row and column, respectively (through a resistor).

So, to use an LED matrix a standard "trick" is employed. The trick is to only light one column of LEDs at any one time, and to rapidly cycle through the columns giving the illusion that two LEDs in different columns are on at the same time. The rows are then synchronized with the particular column that is being "lit" at any one time. Do this over and over — and fast enough — and any set of individual LEDs can appear to be on at the same time.

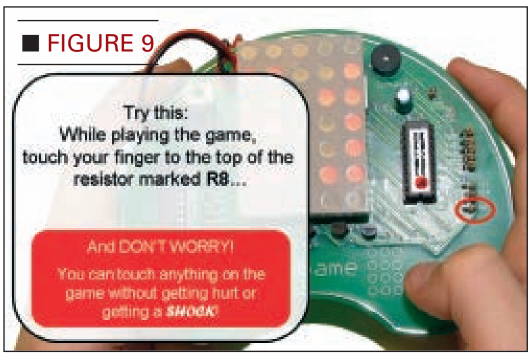
The diagram in Figure 12 is a simplified (though not by much) schematic of the LED matrix in the RetroGame. The resistors have been removed to make it look less cluttered for this discussion. In the RetroGame, the columns are driven by transistors, one of which is on at any point in time. The rows are driven by data that is latched into a data latch.

The algorithm for driving the display is:

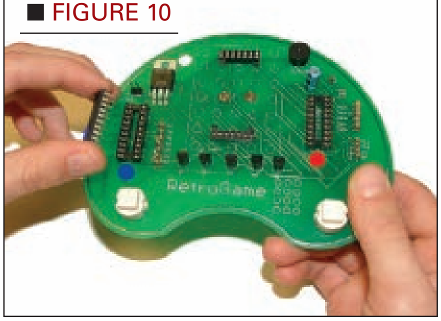
1 – Place the first column data on port B lines 0 through 6 (seven bits). This data corresponds to the particular LEDs which should be lit in the first column.

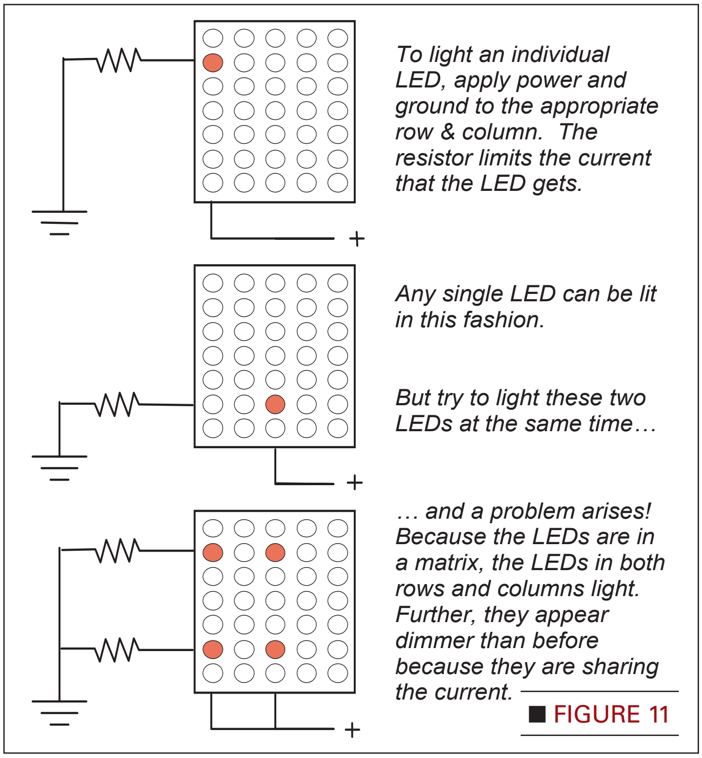
2 – Drive port A bit 0 high, which

■ FIGURE 9

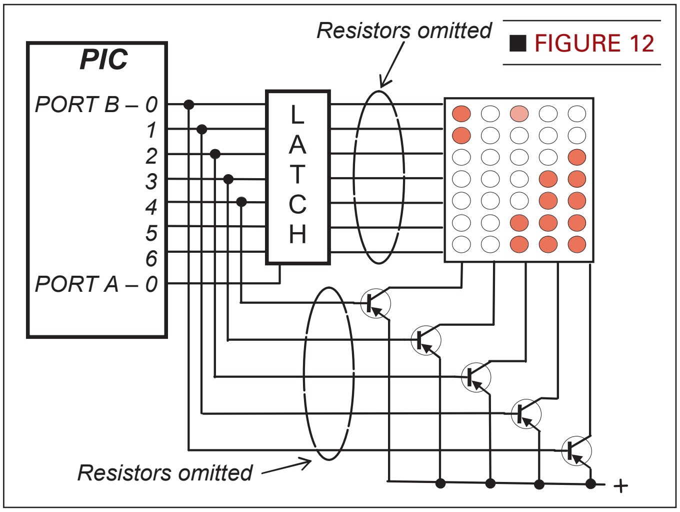


■ FIGURE 10





■ FIGURE 11



■ FIGURE 12

is connected to the data load line of the latch. This both latches in the column data, and holds the latch output lines high while the line is held high — effectively "blanking" the matrix.

3 – Set the column number (the first column in this case) data into port B lines 0 through 4 (five bits). This will turn on the associated column transistor.

4 – Finally, pull port A bit 0 low, which allows the previously latched column data out on the latch output lines, lighting the target LEDs in the first column.

5 – Leave the display in this state for a bit and then start over at step 1 with column 2 data driving the column 2 transistor, followed by column 3 — and so on. After lighting column 5 LEDs, the process starts over at column 1. Do this fast enough and a human observer won't see any flashing. Source code files used for the display are `display.asm`, `display.h`, and `display.mac` (available on the *Nuts & Volts* website).

RetroGame Sound

To generate sounds and music, the RetroGame uses a technique called bit banging. This quaint little term describes the brute-force method of manually raising and lowering a signal line (bit) to generate a particular shape of signal over time on the line. In the case of the RetroGame, the signal is a certain frequency of music or sound.

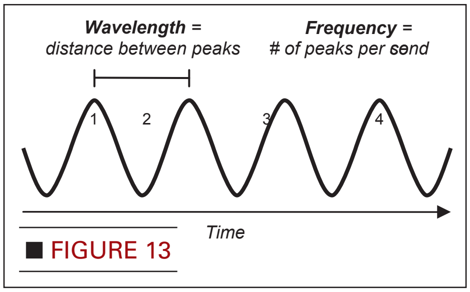
Normally when you see a representation of a sound, or the "waveform" for a sound, you see something like what's shown in Figure 13.

The RetroGame waveform has the same features but looks quite different (see Figure 14.) The PIC generates this waveform by alternately raising and lowering a digital signal at a particular frequency. In other words, the PIC raises the signal line, waits for an amount of time equal to half the wavelength, lowers the signal, waits for another half wavelength, then raises the signal again. The following code snippet is from the RetroGame files (modified to make it easier to read):

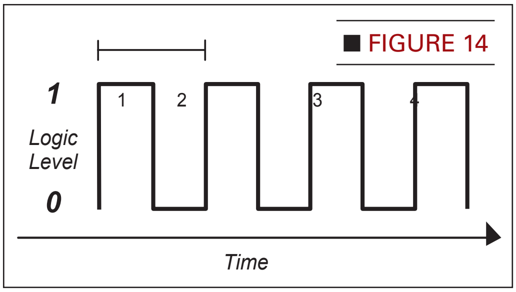
```
#define      SOUND_PORT   PORTA,0x02

Loop:
    bsf      SOUND_PORT
    call     DelayHalfWave
    bcf      SOUND_PORT
    call     DelayHalfWave
    goto     Loop
```

By adjusting the time the PIC waits between the raising or lowering of the sound line, different frequencies can be produced.

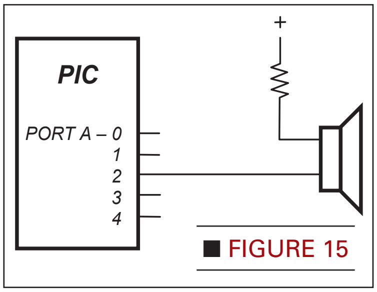
In the RetroGame circuit, the signal line that generates the sound is connected directly to the speaker, with the other end of the speaker connected through a resistor to +5V (Figure 15).



■ FIGURE 13



■ FIGURE 14



■ FIGURE 15

There is a problem with bit-banging like this. While the PIC is generating a sound or music, it can do very little else. In essence, it has to give its full attention to generating the sound. Granted, with some very judicious programming, the time spent waiting between the raising and lowering of the sound line can be used to do other things. This isn't easy, particularly given that music is far more interesting with different frequencies — some of them quite high. Plus, high notes have much less wait time between signal line transitions.

The RetroGame can play two things: music and beeps. To play music, it stops doing everything else, including updating the display. As such, whenever music plays, the display blanks. To make beeps, it is actually smart enough to use the extra time to update and move the display. Source code files used for music and sound are `music.asm`, `music.h`, `music.mac`, `musicdata.asm`, `musicdata.h`, and `musictable.mac` (also available on the website).

RetroGame Software

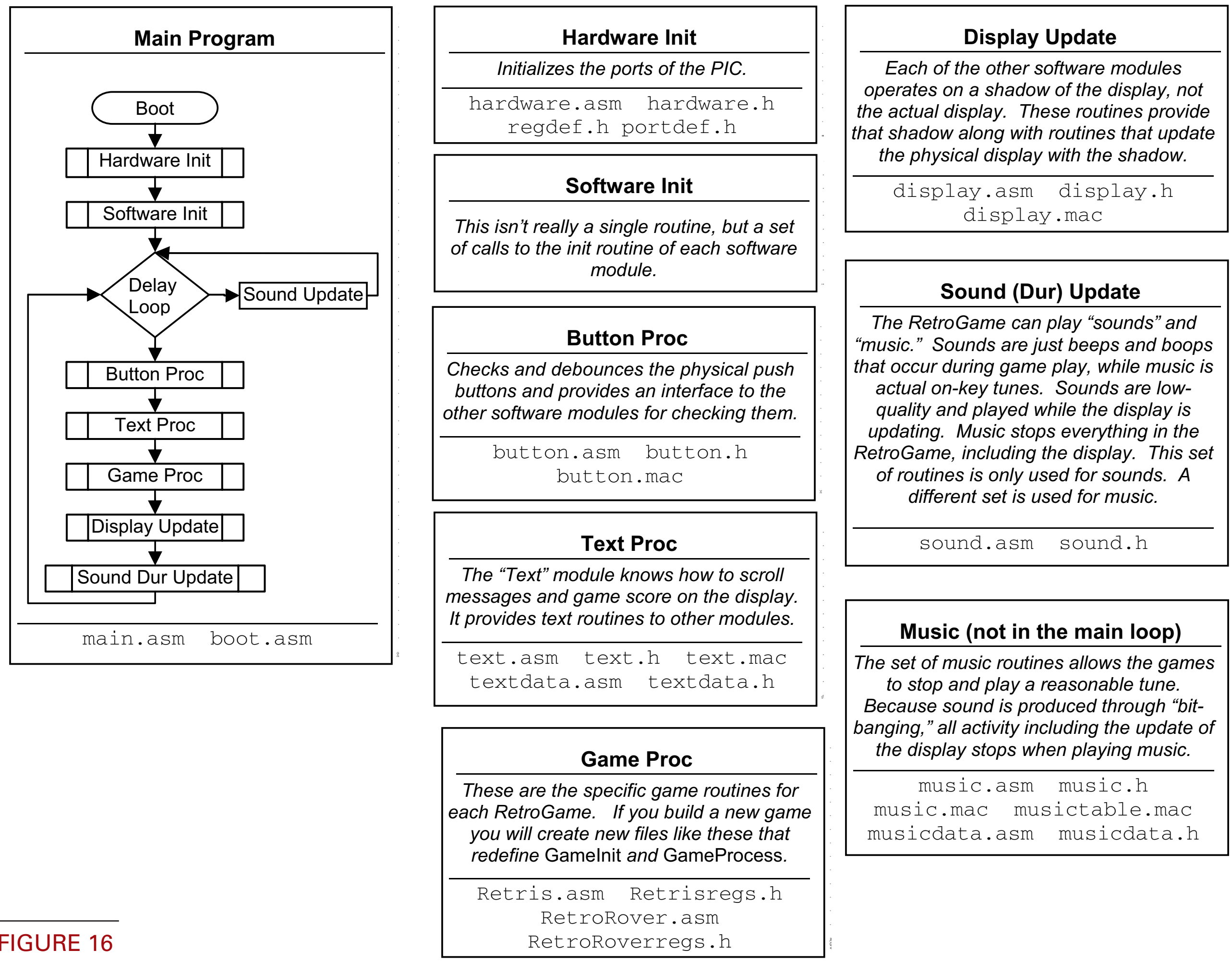
The RetroGame circuit is relatively simple, but the software is somewhat more complicated — not too complicated though, and it is pretty small, fitting into a PIC 16C622A.

All activity in the RetroGame appears to be occurring concurrently. That is, the game is moving on the LED display while sound is being made and the buttons are moving Retris pieces. It should be no surprise, however, that all activity is actually occurring serially but at high speed so you can't tell the difference. In more sophisticated programs on more sophisticated processors, a real-time operating system provides the mechanisms by which many tasks can appear to be operating concurrently. In the RetroGame, however, no real-time OS is used. Instead, a simple brute-force activity loop is employed which:

- Checks the buttons.
- Changes and updates the display (for text or game play).
- Plays beeps and "non music" sounds.

During each round through the loop, a small bit of each software module runs before it returns to the main loop. Each module gets a turn during the loop, accomplishing a small piece of its task and keeping track of its position for the next round with a state machine.

The main loop includes a delay which sets the speed of the game. The only thing that occurs during



■ FIGURE 16

the delay is the production of sounds.

RetroGame Music

The music module in the RetroGame is rather interesting and could easily be adapted for other PIC projects. Implemented in the following source files, the music routines provide an easy mechanism for integrating music into any PIC application:

- **music.asm (.h):** Implements the music playing routines, though none of these routines are called directly. Instead, the macros in music.mac are the interface to music by other modules.
- **music.mac:** Implements the macro "MusicScorePlay" which will play the given musical score. Note that music.mac automatically includes musictable.mac.
- **musictable.mac:** A very large macro that interprets a musical score, setting the appropriate values for the desired note. Note that this entire file is generated by a C program that takes into account the clock speed of the PIC.
- **musicdata.asm:** Musical scores for "standard" game music are in this source file.

As an example of how to use the RetroGame music system, here is a snippet from the source file musicdata.asm:

```
#include "music.mac"

Global       Dirge;

Dirge:
    MusicNoteTableEntry   "C",,2,3,1
    MusicNoteTableEntry   "C",,2,2,1
    MusicNoteTableEntry   "C",,2,1,1
    MusicNoteTableEntry   "C",,2,3,0

    MusicNoteTableEntry   "E","b",2,2,0
    MusicNoteTableEntry   "D",,2,1,1
    MusicNoteTableEntry   "D",,2,2,0
    MusicNoteTableEntry   "C",,2,1,1
    MusicNoteTableEntry   "C",,2,2,0

    MusicNoteTableEntry   "B",,1,1,0
    MusicNoteTableEntry   "C",,2,3,0

    MusicNoteTableDone
```

This snippet creates a data table with a musical score that can later be played with:

```
MusicScorePlay            Dirge
```

The fields of the macro `MusicNoteTableEntry` are:

Field	Description
1*	The musical note: C, D, E, F, G, A, B, or R for a rest.
2*	Modifier for sharp or flat: # or b.
3	Octave – from 0 (zero - low) to 8 (high).
4	Duration from 0 to 3.
5	Set to 0 (zero) for smooth and 1 for staccato.

*Fields 1 and 2 must be enclosed in quotes.

The `MusicNoteTableEntry` macro creates two lines of code per macro. The Dirge score above, therefore, occupies 22 instruction slots, plus two for the `MusicNoteTableDone` macro. In other words, each musical score with N notes occupies 2(N+1) instructions slots.

In Retrospect

To be honest, I'm not sure if I or the kids had more fun with this project. I hope this article will encourage you to step up your game using electronics. **NV**

RESOURCES

❑ **www.rothfus.com/RetroGame**
All of the source files for this project can be found here, including:
- PCB "gerber" files
- Software source code for both games
- Mini-manuals for both games
- Original PowerPoint presentation for Science Day
- Videos of the RetroGame in action

❑ **Sunstone Circuits — www.sunstone.com**
These guys are great! Besides offering an excellent PCB fabrication service, they have a community outreach program that helped pay for the PCBs for the kids. Thanks guys!

❑ **Silicon Hills Design — www.siliconhills.com**
A local electronics assembly and service house in Austin, Silicon Hills graciously assembled the boards for the kids.

PARTS LIST

ITEM	QTY	DESCRIPTION/PART NUMBER
❑ R1-R7 and R17	8	100Ω resistor 1/4 or 1/8 watt
❑ R8-R10	3	10K resistor 1/4 or 1/8 watt
❑ R12-R16	5	1K resistor 1/4 or 1/8 watt
❑ C1	1	10 pF (optional)
❑ C2	1	1 µF
❑ Q1-Q5	5	2N2907 or 2N3906
❑ IC1	1	PIC 16C622A
❑ IC2	1	74LS374N
❑ 5x7 LED matrix	1	(see below)
❑ Speaker	1	Small piezo-electric speaker
❑ Pushbutton	2	
❑ Battery clip	1	Nine volt clip with two pin connector
❑ JP1	1	Two pin battery connector
❑ Battery holder	1	
❑ Small screw/nut	2	For mounting the battery holder
❑ 14 pin IC socket	1	Cut in half to form socket for LED display
❑ 18 pin IC socket	1	Used for 74LS374N mounting (optional)
❑ 20 pin IC socket	1	Used for PIC (optional)

Most of the parts for the RetroGame are easy to find. This table provides sources and part #'s for the hard-to-find parts. The LED matrix is sourced from many suppliers; check to see who has stock (and lowest price!)

ITEM	PART NUMBER	SOURCE
❑ Speaker	AUD1080	BG Micro
❑ Battery clip	BAT1064	BG Micro
❑ Pushbutton	SWT1008	BG Micro
	401-1963-ND	Digikey – white, other colors available
❑ 5x7 LED matrix	604-TA20-11SRWA	Mouser
	LED1115	BG Micro
	160-1560-5-ND	Digi-Key
❑ Battery holder	12BH071-GR	Mouser
❑ PIC	16C622A	Mouser

A PRIMER ON PHASE LOCKED LOOPS

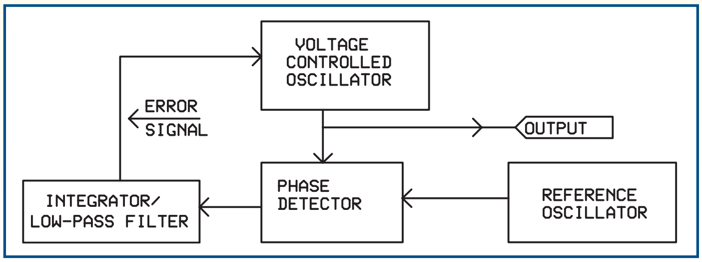
By Gerard Fonte

Phase Locked Loop (PLL) circuits have a number of useful features. Among them is the ability to lock onto a frequency and to synthesize other frequencies. However, in order to realize these features, PLLs must be used properly. This article will examine the fundamental principles of they embody.

Basic PLL

Figure 1 shows the basic building blocks of a typical PLL. It consists of four simple functions connected in a feedback loop configuration. The Voltage Controlled Oscillator (VCO) varies its output frequency according to an input voltage. Naturally, this oscillator must be able to vary over the desired frequency range of operation. It also has a natural frequency (that is, without any control voltage input) that is typically in the middle of the desired operating range. The reference oscillator is the frequency desired. (It may seem silly to design a complex circuit when this frequency is already available, but there are useful applications for this as we will see later.) The phase detector compares the reference oscillator phase and frequency with the VCO phase and frequency to create an error signal. This error signal drives the VCO in the opposite direction (negative feedback) to reduce the error to a very small amount. Since the error signal contains troublesome VCO and reference frequency components, a filter/integrator is inserted to create an error signal that is essentially a DC voltage. However, there is much more to the phase detector and filter/integrator than this. It is important to understand some of the more fundamental considerations of these two blocks in order to learn how a PLL operates.

■ FIGURE 1. The basic PLL consists of four building blocks arranged in a closed-loop operation.



Phase Detector Operation

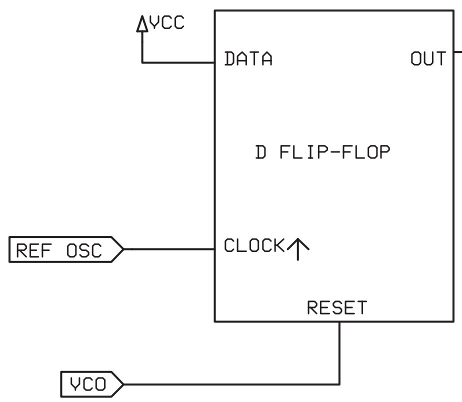
There are two modes of operation in any PLL: capture and lock. In the capture mode, the loop is unstable and searching for a proper frequency. The error signal created by the phase detector drives the VCO towards the appropriate frequency. This takes time — typically around 10 oscillator cycles — but this is extremely variable and dependent upon initial conditions. The precise amount of time depends upon many factors including: phase detector design, oscillator frequencies, filter/integrator design, amount of frequency difference, and other factors. The capture mode of operation is not at all simple. There are many subtle and significant points to consider. It is possible that the circuit will fail and no lock is achieved. It is also possible to have a "local minimum" at a harmonic of the desired frequency and the circuit will lock onto that incorrect frequency. (A local minimum is a point in a circuit's transfer function where a deviation in any direction creates a larger error signal. The feedback design drives the error signal towards a minimum and it cannot distinguish between the absolute minimum and a smaller local minimum. This will only occur in non-linear transfer functions. Phase detector circuits are not always linear.) "Capture Range" defines the ability of the PLL to properly lock onto a signal over some frequency interval.

The second mode of operation is the lock mode. This is the normal operating mode of a PLL. In this case, the phase detector creates a relatively small error signal to maintain the phase relationships between the VCO and the reference oscillator. However, the feedback loop (with the filter/integrator) is not instantaneous. This will cause small inaccuracies in the error signal which is called phase error or phase jitter. Again, it is seen that there are subtle and significant factors to consider. The response of the loop to a change in phase is rapid and only limited by the speed of the whole PLL as a feedback system. "Lock Range" refers to the ability

of the PLL to maintain lock as the reference frequency varies. Generally, the lock range exceeds the capture range.

Phase Detector Design

While it is beyond the scope of this article to provide a comprehensive procedure to design a phase detector, a conceptual design is useful to assist in understanding its basic operation. Figure 2 is a simple D type flip-flop which can be used to illustrate the principles of phase detector design. If the VCO is off (and at logic low), the output will be high because the reference oscillator will clock the logic high that is present at the Data input. If the reference oscillator is off instead, the output will be low because the VCO is constantly resetting the flip-flop. However, it can be seen that if the oscillators are exactly out of phase and precisely the same frequency (and square waves), there will be an exact 50% duty cycle output (minus propagation delays). This 50% duty cycle value will change with different phase relationships.



■ FIGURE 2. A simple D type flip-flip can provide a number of necessary functions of a phase detector.

The point of this exercise is to show how a simple flip-flop provides most of the basic functions necessary for a phase detector. It provides an error signal when there is a significant difference in frequency, which is necessary for the capture mode. It also provides an error signal when there is a phase difference, which is necessary in the lock mode.

A typical digital phase detector circuit (based on the Motorola CD4044 circuit) is shown in Figure 3 (from the 1994 Xilinx data book, pgs. 8-161). Note the cross-coupled AND gates that form Set/Reset flip-flops somewhat similar to the Figure 2 flip-flop. The two outputs are called "pump-up" and "pump-down." These are error pulses that go to the integrator (rather than a filter — discussed more below). The pump-up pulse pushes the integrator value higher and vice versa for the pump-down pulse. There are many other types of phase detectors, including analog versions. However, they all provide a similar type of error signal.

Filter/Integrator

The main purpose of the filter/integrator is to remove high frequency components and provide an error voltage that is essentially a DC value. Note that this "DC" value changes slightly in order to capture and lock onto the signal. It becomes clear that the response of this circuit directly affects the operation of the whole PLL.

For example, suppose you design a great low pass filter that stops all frequencies above 1 Hz. This certainly eliminates any stray high frequency signals from leaking through. However, it severely limits how fast you can change the VCO. There is no way this design would permit frequency-agile or spread spectrum operation where the channels are changed many times a second. The filter simply can't respond fast enough.

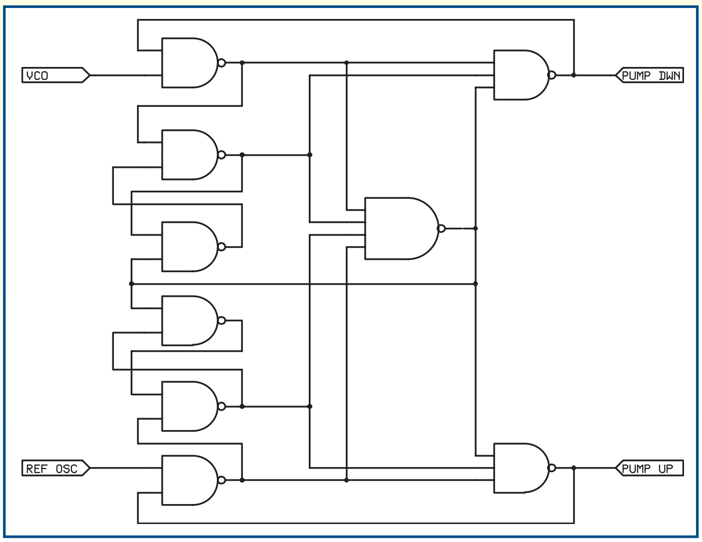
However, if you design the filter for a much higher cutoff frequency you run the risk of allowing noise (from any source) to enter the PLL. This noise de-stabilizes the loop and causes phase noise. You can see that this filter design has a trade-off between rapid frequency shifting and the potential for sensitivity to noise. The actual design must be based upon the expected operation of the PLL rather than some general rules of thumb. This is especially true when low frequencies (such as those used in audio) are being incorporated. In this case, oscillator feed-through is a significant concern.

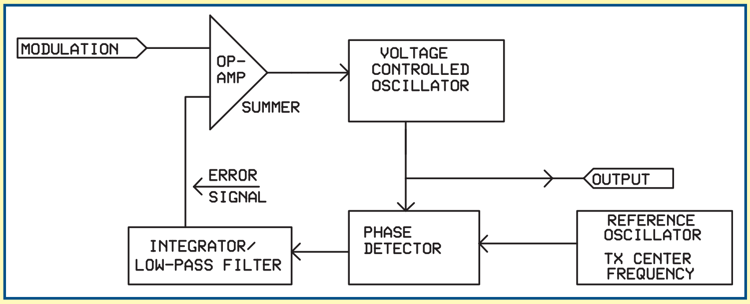
I've stressed the term filter/integrator rather than just filter because the idea of an integrator makes this block easier to understand. Basically, an integrator continuously sums the values applied to it. In the case of the PLL, the positive pump-up and negative pump-down pulses are seen to sum to zero when the PLL is locked. There are an equal number of positive and negative pulses. It can also be seen that if there is no error, there is no change in the integrator output (adding zero does not change the sum). This concept is obvious when discussing an integrator but much less so when discussing a filter. It should be noted that a simple RC (resistor-capacitor) filter is adequate and appropriate for many designs.

Applications

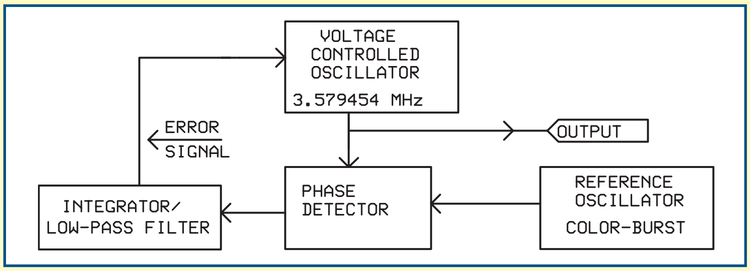
The basic PLL as shown in Figure 1 has a number of

■ FIGURE 3. A real phase detector circuit shows a number of interconnected S-R flip-flops somewhat similar to Figure 2. The operation of this circuit is not intuitively obvious.





■ FIGURE 4. This is an FM modulator. By adding an op-amp, a modulation signal can be added to the error signal. This causes the VCO to change its operating frequency according to that modulation signal.



■ FIGURE 5. This circuit uses a "pullable" crystal oscillator as the VCO. It locks to the short color-burst signal included in the video signal and maintains the phase even when the color-burst signal is absent.

common and important applications. The first is FM demodulation. Make the VCO the tuning oscillator in an FM receiver and make the received frequency the reference oscillator. Once the system is locked, the error term will be a representation of the modulation signal (that is, the audio signal). Many early FM receivers used this simple and effective technique.

The PLL can also be used as an FM modulator as shown in Figure 4. In this case, a crystal oscillator of the desired frequency is provided as the reference oscillator with an ordinary VCO in place. The special twist is to use an op-amp as part of the filter/integrator (however for clarity, it is shown as a separate block in the figure). The desired modulating voltage is applied to the non-inverting input of the op-amp. The amplitude of this signal is matched to the VCO to provide the appropriate modulation range. This provides the stability of a crystal oscillator while allowing the output frequency to be adjusted over a few kHz. The linearity of VCOs can be very good which results in the high fidelity modulation necessary for FM stereo broadcasts.

Another common use of the basic PLL design is in color TV sets. Here, the 3.579545 MHz color-burst signal must be reproduced with precision in order to create faithful color on the screen. However, the color-burst signal only lasts for a very short time over the whole scan line. Any color-phase deviation during that period can ruin the color. How can the proper color-phase relationships be maintained if the color-burst is not available? The PLL comes to the rescue — take a look at Figure 5.

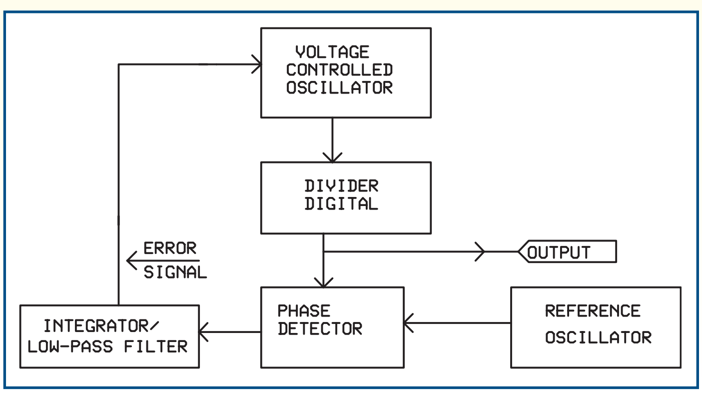
In this case, the VCO is a 3.579545 MHz crystal oscillator that is "pullable." That means that its frequency of oscillation can be changed by a small amount (usually a fraction of a percent) with the application of a DC signal. The reference signal is filtered to only allow the 3.579545 MHz color-burst signal (transmitted by the TV broadcaster) into the reference oscillator. In theory, these 3.579545 MHz frequencies should be the same. In reality, they're not but are very close. The error between them is probably about 500 ppm (parts per million) worst case (0.05%) which is within the pullability of the VCO. Since these frequencies are already so close, there is really no capture mode for this design.

The result is that the VCO will phase-lock to the reference oscillator just as fast as the loop will allow. Within a cycle or two, the loop is locked but then the reference signal goes away. What happens to the VCO? If you think of the filter/integrator as a filter, the operation is not clear. But if you think of it as an integrator, the process is elementary. The PLL loop will maintain the last lock because there is no error signal of any type to sum. As noted above, adding zero to a number doesn't change that number. The result is that the VCO is locked to the transmitted color-burst signal and maintains that lock throughout the whole scan line. The VCO is re-locked on the next scan line and every other scan line. In this manner, the TV can maintain the proper color-phase relationships even though the reference oscillator is active for only a small percentage of the time.

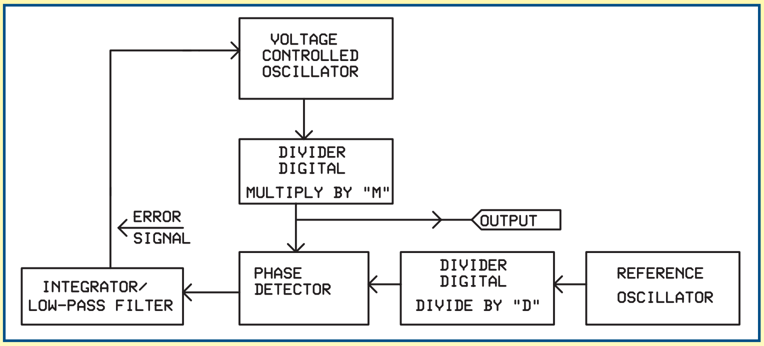
Applications II

Now that we understand how the PLL works, we can see how it can be used for frequency synthesis. Suppose we put a digital frequency divider between the VCO and the phase detector as in Figure 6. What happens? Well, it's clear that the phase detector sees a frequency that is too low. It will force the VCO to increase the frequency until a lock can occur. It is also apparent that the new VCO frequency must be the product of the reference oscillator frequency and the division value.

If the digital divider reduces the VCO frequency by a factor of 10, then the phase detector will push the VCO frequency up by a factor of 10 to match the reference frequency. This is (integer) frequency multiplication. Again, the nice feature



■ FIGURE 6. Adding a divider circuit between the VCO and the phase detector has the effect of forcing the VCO to increase in frequency by a reciprocal value. This is integer frequency multiplication.



■ FIGURE 7. Adding another divider circuit after the reference oscillator causes the VCO to decrease by the same factor (integer division). Using two dividers at the same time allows fractional frequency division and multiplication by M/D times the reference oscillator frequency. This is a very useful concept.

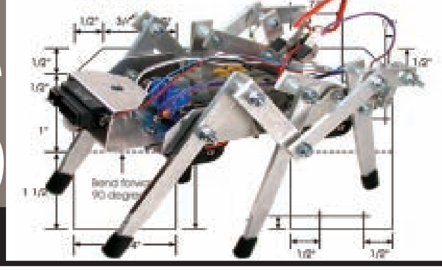
is that the new frequency is just as stable as the crystal-controlled reference oscillator frequency. Making the divider adjustable allows many different frequencies to be generated simply by changing the divider value.

Another procedure is to change the reference oscillator frequency with a digital divider. The change in circuit operation is basic and obvious. The VCO will change to match the new reference frequency. Since the circuit divides by some value, the VCO output frequency will also be the reference oscillator frequency divided by that value. This is (integer) frequency division and by itself doesn't have all that much utility.

However, when coupled with the frequency multiplication concept (above) and as shown in Figure 7, a whole new animal emerges. The divider circuit allows integer frequency division by some value we'll call "D." The multiplier circuit allows integer frequency multiplication by some value we'll call "M." Both multiplication and division refer to the reference oscillator frequency. By combining both circuits, fractional multiplication and division are possible. The VCO output will be M/D times the reference oscillator. If the digital dividers are both capable of dividing from 1 to 1,000, then the output frequency can be from 1/1000 to 1000/1 times the reference oscillator frequency. This is a very useful approach. A virtually unlimited range of frequencies can be generated from a single crystal and all of these frequencies are just as stable as the basic crystal oscillator (minus loop noise/phase jitter).

Conclusion

The PLL is easy to understand once you grasp the operation of the phase detector. This is the key to PLL operation but is often overlooked and not well appreciated. It is useful to be able to design with the PLL because we have seen that it has many useful features and can perform operations that would otherwise be impossible or impractical. **NV**



■ BY VERN GRANER

ROBOT ART

"Where the spirit does not work with the hand there is no art." — Leonardo da Vinci

WHAT IS ART? This is a question that has been debated over the years by both the greatest and the least among us. It is generally held that, like beauty, art is subjective — judged by each person who encounters it. Humans appear to be drawn to leave their mark on just about any blank media they encounter. Artists and their works have been with us since the days of cave paintings and stone sculptures.

Yet, for such a pervasive subject, "art" has proved amazingly hard to define. The concept is so flexible, it may be used to describe works created in traditional tangible mediums such as paint, marble, metal, and wood, as well as the less tangible forms such as music, plays, poetry, and dance. As technology has touched on each of these mediums, it's no wonder that we see art absorbing and reflecting technology. The works of artists are usually shaped by the environment that surrounds them. As modern life is immersed in technology, it's only logical that we would start seeing technology in our art and even technology as art.

WHAT'S ROBOT ART?

In preparing this article, I found the simple phrase "Robot Art" to be interesting in that it is delightfully ambiguous. For example, it could be taken literally to mean artworks produced by a robotic apparatus. It could also refer to conventional art (such as sculptures or paintings) that feature robots as their subject or inspiration. We could even view the robot itself as a manifestation of art!

In an attempt to explore some of the interesting and inspiring ways art and technology intertwine, this month we will focus on a number of works from some talented techno-artisans who have used technology and robotics to pursue their muse in interesting and ingenious ways.

ROBOTICIST = ARTIST

I have yet to meet a roboticist that was not an artist (though some seem reluctant to admit it), yet their works may require a paradigm shift in order to be seen. If you look at things just a bit differently, you may find art in surprising places. Look closely, and you may see that programmers are actually writing functional poetry, bound by tighter rules even than Haiku or iambic pentameter. You may find that — exactly as a sculptor does — machinists strive to free their visions from within a plain block of material.

In some cases, only a privileged few will ever get to see the visual artworks of astounding complexity and beauty created by integrated circuit engineers. Encapsulated in opaque black epoxy and mounted on printed circuit boards, these functional masterworks are tragically hidden away behind the mundane faceplates of various consumer electronics devices.

In the early days of electronics, printed circuit boards were drawn by hand and called artwork. In the days before CAD layout software was available, you could clearly see evidence of the "human touch" in PCB design. Though components were often laid out with military

■The Antikythera mechanism is an ancient mechanical device designed to calculate astronomical positions. Scientific examinations place its date of creation to be between 150–100 BC.

precision, the PCB draftsman would usually create smooth, sweeping traces that wound their way from part to part guided by function, yet aesthetically placed by the eye of the layout artist. As evidenced by studying the Antikythera mechanism, it is clear that artist-engineers have been intimately involved in the integration of art and technology from as far back as 100 BC (see Resources).

THE ROBOT GROUP

Regular readers will notice I often mention The Robot Group in Austin, TX. I am privileged to be a member of this long-lived consortium comprised of some amazingly diverse, talented, and (truth be told) occasionally eccentric people. Some might go so far as to dub these folks "artists" that do their very best to live up to the city motto, "Keep Austin Weird." The group is an excellent example of folks who mix art and technology regularly and well. I've explored the offerings from some of our more prolific members, so this time I'll start with one of the newer members.

MARVIN "PROFESSOR CONRAD" NIEBUHR — FLIM FLAM LABORATORIES

I met Marvin at Dorkbot Austin in October 2006 where he had on display his collection of "Biomechanical" devices. Marvin had created an entire fantasy panorama populated with fanciful creatures crafted from re-purposed toys and technological cast-offs.

■ The Screamin' Babyheads Band at SxSW.

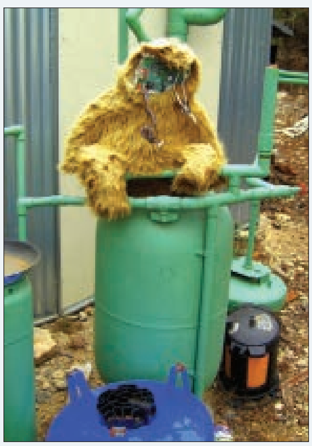
He methodically deconstructs and recombines the parts to build the characters and sets that tell an engaging story. Being retired, Marvin has free time in abundance. With his classically trained art skills, extensive real-world experience as a carpenter, architect, and builder, and a voracious appetite for construction, Marvin has continued to bring out new creations and new story lines to support them at an astounding rate. Not stopping with the purely visible, Marvin went on to create the "Screamin' Babyheads and the Instruments of Mass Distortion" band using both traditional and circuit-bent instruments to manifest an exciting and whimsical (and yes, humorously disturbing) musical tableau. He has recorded one album of material ("Heads Above Ground") and is working to create more (see the sidebar).

His most recent creation — the "pPod" — places a cast-off car stereo inside a hand-crafted "pea pod" sculpture. He mounted a recycled 12V PC power supply inside a stylized sun to provide "solar power" for the system and then mounted tubes on tripods to hold the coaxial 5-1/4" speakers. A sub woofer system contrived to look like cactus completes the ensemble with meaty bass and twinkling blue LEDs.

A quick walk around his house (a.k.a., Flim Flam Laboratories) reveals a panorama of artworks that decorate and infuse the area with fun. His abundant proclivity to create is aptly displayed. The results of his experiments at Flim Flam Labs are scheduled to appear at the SxSW music festival, Dorkbot, and other events around central Texas. If you find yourself at a festival in Austin, look around for Marvin.

He'll be the one in the white lab coat with the chili-pepper helmet.

■ Flim Flam Lab's all sports trophy.



■ Failed experimetal Biomechanical.

MICRO BIO

Marvin Niebuhr, a.k.a., "Professor Conrad" of Dripping Springs, TX, is a performance artist creating musical sculpture and fine art pieces in mixed medias. His musical works have been featured at events such as Maker Faire, Dorkbot, SxSW, The Robot Group, Transparent Mic, and local music venues such as the Scoot Inn, Schultz Beer Garten, and Jack Mountain Outpost. His sculptures have been shown at LewAllen and LewAllen in Santa Fe, NM, and he has recently become an artistic adviser at the Stock Movie Company of Smith Creek Studios in Texas Hill Country. He holds a B.F.A. from Bradley University, an M.A. from New Mexico Highlands University, and is a retired Professor of sculpture from The University of Texas-Pan American. To see more of his works, visit him online at **http://flimflamlab.blogspot.com**.

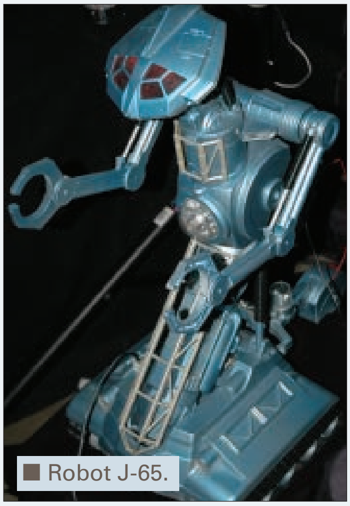
■ "Professor Conrad" plays the Optical Theremin at the Transparent Mic concert.

JOHN P. FUNK — "THE QUEST FOR THE DARK PLANET"

Unsurprisingly, Dorkbot is an exceptionally good place to meet artists that create with technology. I met John at a Dorkbot presentation where he was displaying his amazing J-65 robot. Built as a prop for his upcoming '70s-style miniature model movie, "The Quest for the Dark Planet," the J-65 is a tribute to looking at things differently and rearranging the mundane into the extraordinary. J-65 sports multiple physical motions including head tilt, body pan, arm raise/lower, and a series of lighting effects to accompany his moves.

John has brought J-65 to multiple Robot Group events, including the Alamo Draft House premiere of "Wall-E," Maker Faire Austin, and multiple Dorkbots. In addition to creating this completely animated robot movie prop, John has also created an entire cast of miniature figures, space craft, and a comprehensive movie set that he can animate with radio control for taping action sequences. His detailed set design work shows a plethora of skills in electronics, painting, sculpting, model design/fabrication, and, of course, camera work and editing.

Like our esteemed Professor Conrad, John also writes and performs his own music. It's not unusual to find John performing at local tech/art gatherings here in Austin. Be sure to check the Resources section for links to his creations including a teaser movie trailer for, "The Quest for the Dark Planet."



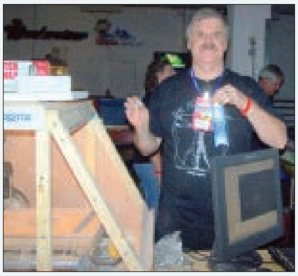
■ Robot J-65.

■ Robot J-65 entertains children at the Wall-E premiere.

MICRO BIO

John P. Funk is a self-made, multi-disciplinary artist. He incorporated his first LED light in a original spaceship model in 1978 a year after he saw "Star Wars." John has a unique process of recycling old toys, circuit bending electronics/LEDs with Kit Bashing model kits comprised of mostly recycled materials. John started a home-based independent VFX company after leaving the computer gaming industry in late 2004. John is currently creating his own original universe in the short film "The Quest for the Dark Planet." John participates with many groups and clubs in Austin including the Robot Group and the 3D Studio Users Group, etc. His work has been seen at Sci-fi conventions in Texas, as well as Austin Maker Faire 2007-08, Burning Flipside, SxSW Plutopia party, Dorbot Austin, and The Artspark Festival. His website is **www.cozmicfunk.com**.

PAUL ATKINSON — DIGITAL LIFESAVER



■ Paul Atkinson stands next to the PROBOTIX Fireball v90 CNC system, after winning the "Editor's Choice" award.

It seems that just about every recent project the Robot Group has done has Paul Atkinson's metaphorical fingerprints on it. An electrical engineer by day and technological super-hero after hours, Paul has assisted the Robot Group members with darn near every project we've created in the last five years: the PONGINATOR, the RoboSpinArt Machine, the PingPongPrinter, and, of course, the PROBOTIX Fireball v90 CNC Router, just to name a few! When not rushing to the aid of his fellow Roboteers, Paul has spent what little free time he has becoming rather proficient with the PROBOTIX system. Not only did Paul assemble the unit and document it for the Personal Robotics column here, he has gone on to explore and improve the device, swapping out the Dremel tool for a new Colt router and working extensively with software from Vectric (see Resources) to create new works of art. For example, Paul used Vectric's V-Carve Pro to design and cut a series of wooden sculptures for his wife. He also cut some 3D artwork such as a Christmas wreath using patterns he downloaded from the Vectric website. A series of techno-snowflakes were to follow, made entirely from recycled CD-ROM media. As there is interest from a number of our Roboteers in casting and creating molds, Paul is currently experimenting with building and cutting 3D models in foam and other media.

■ CD-ROM snowflakes cut from recycled CDs by Paul Atkinson.

MICRO BIO

Paul Atkinson is an electrical engineer in Austin, TX. He holds a BS EE from North Carolina State University and has had a career-long interest in robotics and electronics. He is a member of The Robot Group and collaborates on many of their projects. Recent work includes building and operating a Fireball CNC router, developing a commercial tube winding machine, developing a DC-DC switcher for a wild-life camera, and circuit design and PCB layout for an LED sequencer. He has participated in Maker Faire Austin, EFF-Pultopia, SxSW, Dorkbot, and other regional events.

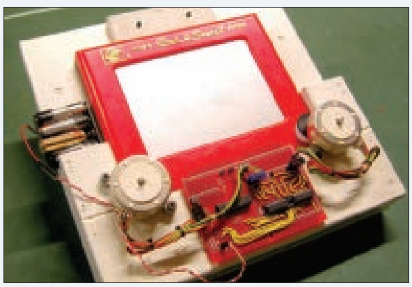
NYSSA HUGHES AND JAMES DELANEY — MAGIC SCREEN MACHINE AND TECHNO ART

■ Nyssa Hughes and James Delaney prepare to present a project at The Robot Group weekly meeting.

I met James and his wife Nyssa back in 1995. James was a Unix system administrator for a community college and had been working with both software and hardware for a number of years. Nyssa had been sculpting, painting, and crafting artworks for that long or longer. After a bit (well, maybe more than a bit) of cajoling, I finally managed to get both James and Nyssa to come out to the Robot Group meetings. Now, they're a regular feature bringing in new devices and creations to just about every meeting. At one of these meetings, James got a chance to see the award-winning PROBOTIX Fireball CNC machine I detailed my December '08 column. Upon seeing the unit in action, James decided he wanted to experiment with computer motion control and stepper motors. Inspired by similar projects found around the Internet, he enlisted the help of Paul Atkinson and Bob Sheldon in the creation of his own X/Y vector drawing system designed to etch patterns on a simple, reusable display.

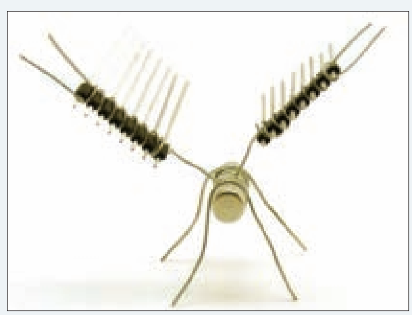
Using the ATMEGA8 Development Kit by ProtoStack, James built a microcontroller system that could receive and process standard computer parallel port signals to control stepper motors. He then attached the stepper motors to the X and Y direction knobs on a second-hand Etch-a-Sketch® "Magic Screen" to create his "Magic Screen Machine." Using a series of GNU/Open Source programs, he drew a version of the Robot Group's logo and controlled the stepper motors to draw the logo on the screen. Make sure you check the Resources section for a link to James' page with a full write-up, source code, schematics, and links to all the software he used to make the finished Magic Screen Machine. While James has been working diligently on hardware and software for his projects, Nyssa has been busy working on techno-inspired devices such as the award-winning Micro RC Jousters. Using small radio-controlled cars with fanciful paper bodies and magnetically mounted "jousters," two operators can drive their electric "steeds" and recreate the fun and excitement of a renaissance festival joust with a side order of origami. Like James, Nyssa shares all the details on how to recreate her work on her website. She even has a nice how-to video that shows the jousters being made and then actually fighting!

■ The Robot Group logo as displayed on the Magic Screen machine.



■ The finished Magic Screen machine.

Though jousting may be jolly good fun, Nyssa has put down the remote controls long enough to create some technology-inspired works including the acrylic on canvas painting entitled "The Brain" and the vector art drawing entitled "Robot Head" that was used to make a limited series of custom t-shirts. She has also created many small sculptures using electronics components, including such works as the aptly named "Fuse Bug."



■ "Fuse Bug" sculpture.

MICRO BIOS

Nyssa Hughes is a painter, sculptor, and T-shirt designer, based in Austin, TX. Her works have been featured at The Robot Group and Maker Faire. She won an Editor's Choice ribbon at Maker Faire and was a runner-up in the "2008 National Pabst Blue Ribbon 2008 Art Contest." Recently, she participated in The Dallas Museum of Nature & Science Tech Fest, where she exhibited her Micro Remote Control Jouster cars. See examples of her work at **www.nyssa.com**.

James Delaney is an inventor, photographer, graphic artist, and Linux SysAdmin. His inventions include the PROFC LED Sequencer, the Trampoline Sensor MKII, and the UBUSB Hallucination Generation device, and have been featured at events such as Maker Faire, EFF Plutopia, and The Robot Group. His technique for altering digital photos by using color palettes derived from classic paintings has been featured on dozens of blogs and has made the front page of digg, del.icio.us, lifehacker, and MAKE: blog. Delaney's graphic art has appeared on posters and the covers of CDs and DVDs. His video animations have been utilized in such documentaries as the national PBS series "Visiones" and "I Love My Freedom, I Love My Texas," and the royalty free backgrounds "nMotions." He lives in Austin, TX. To find out more visit: **www.unfocusedbrain.com/**.

CRAIG GOLDSMITH — THE CLOCKWORK FAIRIES

When I started on this article, I had fully intended to only feature the creations of people in The Robot Group for a number of reasons, not the least of which is that I would be able to lay hands on any of the projects to verify their authenticity and to get pictures for the article. So far, all of the works featured have been created by Robot Group members. However, I came across a labor of love from a dad to his daughter and I just had to include it, as well.

I was touring the Completed Projects section of the Parallax online forums when I saw an amazing device created by Craig Goldsmith (a.k.a., "Zoot") for his daughter. Having created things for my children as well (see Peanut Butter Monster Detector, October '08) I felt a resonance with Craig and his one-of-a-kind project, "Clockwork Fairies."

Based around the Parallax SX series microprocessor, the Clockwork Fairies is a tour de force in electronics and enchantment. In his own words from the online posting, this is what Craig had to say about his creation:

■ Craig Goldsmith's "Clockwork Fairies" project.

"Here's a little something I constructed as a holiday gift for my daughter. Wooden box with acrylic front, prismatic flowers, LEDs, and "clockwork" fairies.

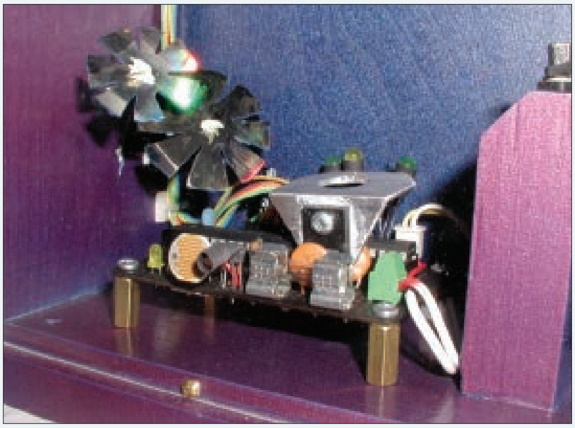
The LEDs cycle through various patterns; the LEDs inside the box cast interesting reflections around the inside. When the user waves their hand in front of the IR emitter/detector pair, a small gearbox motor cranks the fairies back and forth for a random time.

A small photo resistor detects when the lights have been shut off — in that case, the box shuts down with the LEDs dimly twinkling and nothing will start the motor. In the morning, it "wakes" up after several minutes of daylight.

The circuitry is built around a Parallax SX-series microcontroller, which is used for driving some of the LEDs, the IR pair, and sigma-delta ADC on the CDS cell. A ULN2803a sink driver runs the motor and the LED bank inside the box.

The SXB/assembly code cycles through the patterns at different speeds; a flag set by the main state machine lets the LEDs either be run in a bitmap "pattern" mode (each LED is on/off) or PWM mode, where each LED can have PWM brightness level and ramp speed set. The effects are quite striking — at high speeds, the bitmap patterns approach "solidity;" the PWM random modes are very "twinkly."

The fairy art was created by me and printed to high-quality matte photo paper (the kind with plasticized finish), and mounted to air-craft plywood cutouts and trimmed. The rest of the construction was just from bits I had lying around."



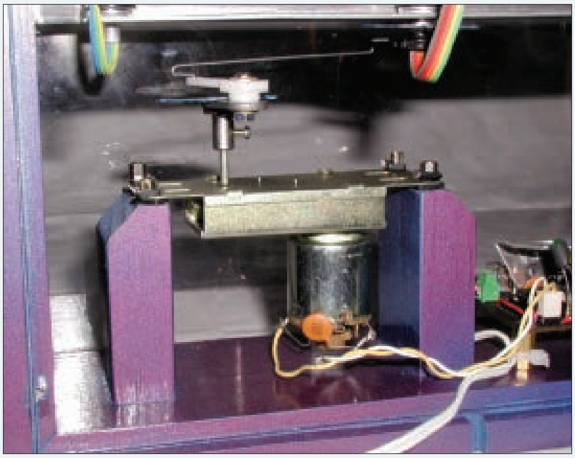
■ The PCB hosts LEDs, CDS cells, IR Emitter/Detector pair, and prismatic flowers.

Incorporating sensors, motors, lights, software, experience, and no small amount of talent, Craig was able to make an entertaining and utterly delightful personal gift that could be passed down through generations of their family. A true labor of love and an excellent closing example of what can happen when art and technology are skillfully mixed.

Craig has graciously posted all the source code, schematics, and pictures to help others make their very own animatronic sculptures. Make sure you check the Resources section for the direct link to his forum post.

MICRO BIO

Craig Goldsmith is a graphic, object, interactive, and embedded electronics designer based in Albuquerque, NM. He is also the host of the seminal "Coffee Express" participatory radio program on KUNM-FM. Visit his website at **http://1uffakind.com**.



■The gearhead motor that drives the animatronic motion.

ALL GOOD THINGS ...

In closing, I'd like to thank all the artists who contributed to the works featured in this article. I would also like to encourage you to explore your own artistic urges or to share your stories about art and technology with me.

Please feel free to come by the *Nuts & Volts* forums to chat or contact me by email at vern@txis.com. **NV**

RESOURCES

■ The Robot Group
www.TheRobotGRoup.org

■ The Antikythera mechanism
http://en.wikipedia.org/wiki/Antikythera_mechanism

■ Keep Austin Weird
http://en.wikipedia.org/wiki/Keep_Austin_Weird

■ Professor Conrad's "Screamin' Babyheads and the Instruments of Mass Distortion" videos
www.youtube.com/user/screaminbabyheads

■ John P. Funk's "The Quest for the Dark Planet" trailer
www.youtube.com/user/cozmicpfunk

■ James Delany's Magic Screen project
www.unfocusedbrain.com/projects/2009/cncmagicscreenmachine

■ Jeff Epler's AXIS CNC page
http://axis.unpythonic.net/index.cgi/etchcnc

■ ATMEGA8 Development Kit by ProtoStack
www.protostack.com

■ Inkscape GNU/Open Source drawing program
www.inkscape.org

■ EMC2 GNU/Open Source CNC program
www.linuxcnc.org

■ PROBOTIX v90 Fireball CNC system
www.probotix.com

■ Nyssa Hughes RC Jousters site
http://blog.nyssa.com/site/?page_id=25

■ Paul Atkinson's web page
http://wiki.therobotgroup.org/wiki/PaulAtkinson

■ Vectric CNC Software
www.vectric.com

■ Craig Goldsmith's Clockwork Fairies
http://forums.parallax.com/forums/default.aspx?f=21&m=322984

■ Parallax SX processors
www.parallax.com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robot diameter is 3π cm (~3.7 inches)
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■ BY RON HACKETT

TAMING UNRULY LCDs: PART 1

IN THE PREVIOUS INSTALLMENT OF THE PICAXE PRIMER, I said we would turn our attention toward interfacing our Master Processor with inexpensive LCD displays based on the Hitachi HD44780 controller (for more info, see "Getting Started with PICAXE Microcontrollers, Part 2" in the Feb. 2007 issue of *Nuts & Volts*). These displays are easy to work with and they can be extremely useful in a variety of projects. We will be focusing on four specific Hantronix displays (see Figure 1) that I chose because they are inexpensive ($5 to $10) and have pin-outs that are fairly easy to adapt to the construction of stripboard circuits. The displays are available at www.Mouser.com; go to their site and enter the Hantronix part number from Figure 1 to get pricing information and to download the datasheets.

While in future installments of the Primer we'll develop stripboard circuits for each of the display sizes (16x2 and 8x2), this month we'll focus on simplifying the interface between our Master Processor board and both sizes of the parallel displays.

Pin	Symbol	Function
1	Vss	LCD Power Supply (Ground)
2	Vcc	LCD Power Supply (+3 to +5 Volts)
3	Vee	Contrast Control (Analog) (Consult Data Sheet)
4	RS	Register Select Input (H=Data; L=Command)
5	R/W	Read/Write Input (H=Read; L=Write)
6	E	Enable Input
7	DB0	Data Bus I/O Bit 0 (Not used in 4-bit mode)
8	DB1	Data Bus I/O Bit 1 (Not used in 4-bit mode)
9	DB2	Data Bus I/O Bit 2 (Not used in 4-bit mode)
10	DB3	Data Bus I/O Bit 3 (Not used in 4-bit mode)
11	DB4	Data Bus I/O Bit 4
12	DB5	Data Bus I/O Bit 5
13	DB6	Data Bus I/O Bit 6
14	DB7	Data Bus I/O Bit 7
15	A	Optional Backlight Anode (Consult Data Sheet)
16	K	Optional Backlight Cathode (Consult Data Sheet)

■ FIGURE 2. Standard HD44780-based LCD pin-out.

The Hantronix units that I'm using are of a fairly standard size, so you may already have one or two small HD44780-based displays on hand that will also work with our circuits. If you want to be sure your displays are suitable, download the Hantronix datasheets for both display sizes and compare your displays to the detailed "Dimensional Drawing" included in the datasheets (**www.hantronix.com**). If your display is sized slightly differently, all you need to do is to adjust the size of the stripboards you build.

All HD44780-based LCD displays share a standard pin-out, which is presented in Figure 2. The first 14 pins are always present and if the display includes a backlight, pins 15 and 16 are used to power it. For our purposes, the most important consideration is the positioning of the I/O connector on the LCD display. For the two line by eight character displays, the connector should be on the left side of the board and should contain two rows of seven or eight pins (non-backlit vs. backlit); for the two line by 16 character displays,

	8 Chars X 2 Lines	16 Chars X 2 Lines
No BackLight	HDM08216H-3-S00S	HDM16216H-5-S00S
BackLight	HDM08216L-3-L30S	HDM16216L-5-E30S

■ FIGURE 1. Selected Hantronix LCD displays.

the connector should be on the top edge of the board and should contain one row of 14 or 16 pins (again, non-backlit vs. backlit). These two pin configurations greatly simplify the stripboard layout, but you could also modify the stripboards to accommodate different configurations.

Now that I have mentioned backlit displays, it's a good time to issue a little warning about them. Since the backlighting is LED based, a current-limiting resistor is generally a necessity, which creates two problems for us. First, you need to read the datasheet to determine the size of the current limiting resistor and it's rarely stated directly — you need to find the values for two important specifications of the display and perform a little computation. The Hantronix datasheets, for example, state that the typical forward voltage (V_f) across the backlight is about 4V, and the maximum forward current (I_f) through the backlight is 120 mA.

With a 5V supply, that leaves 1V to be dropped across the current-limiting resistor, so 1V / 120 mA = 8.3 Ω as an absolute minimum safe size for the current-limiting resistor. To be conservative, let's say 10Ω, which I have on hand but didn't have the courage to try! Instead, I used a 27Ω current limiting resistor for my backlit Hantronix displays. Since 1V / 27Ω = 37 mA, I'm well within the limit and the displays are comfortably bright to view. If you use a different LCD brand, you will have to do similar calculations to arrive at a safe value for your current limiting resistor.

The second problem is related to the first — you need to exercise extreme caution when interchanging backlit displays on the stripboard circuits. For example, I have a very nice blue and white display that requires a 330Ω current limiting resistor. If I carelessly inserted it into a stripboard with a 27Ω resistor, powering it up would almost certainly fry it! So, the safest approach for backlit displays is to first determine a conservative size for the current limiting resistor, and then leave that display attached to its specific stripboard. Of course, this caution doesn't apply to non-backlit displays, which don't even connect to pins 15 and 16 anyway.

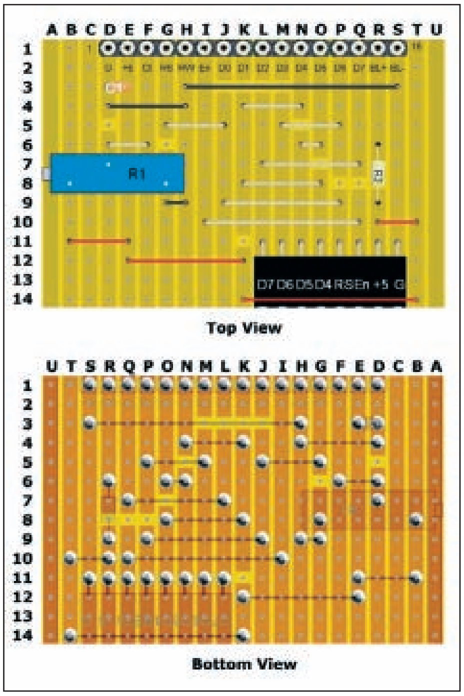
In the following discussion, I'm going to focus on the details of the stripboard construction. I'm not going to repeat all of the LCD information discussed in the article that I mentioned earlier (*N&V*, Feb. 2007). Hopefully, you have an available copy on hand; if not, the third section of the PICAXE manual (available from Revolution Education) is entitled "Microcontroller Interfacing Circuits." It contains a wealth of information on interfacing various I/O devices to PICAXE processors; pages 30 through 41 deal with HD44780-based LCDs with PICAXE processors. Another valuable resource for information on PICAXE-LCD interfacing is **www.hippy.freeserve.co.uk/picaxelc.htm**.

SIMPLIFYING THE PARALLEL INTERFACE FOR A 16x2 LCD

Of course, what we are about to do is not at all necessary to interface a parallel LCD display to a PICAXE processor — we could simply solder a male or female header to the display and connect the eight required lines to the appropriate positions on our breadboard. However, this approach quickly gets messy, and as a result it is somewhat error prone. The stripboards we'll construct completely eliminate the need for wires, at least for the 28X1 processor — the boards can be directly connected to the 28X1's I/O lines just by inserting them into the breadboard.

Before we construct our first stripboard, I need to mention something about the header connections involved. Most LCD boards do not come with a header installed; just one or two rows of holes into which you can solder either a male or female connector. The very first LCD that I interfaced to a PICAXE circuit had one row of 14 holes along its bottom edge. Since I wanted to insert the LCD into a breadboard, I simply soldered a 14 pin, right-angle male header to the LCD. However, I soon discovered a problem with this approach. Since the LCD I was using wasn't backlit, I found I frequently needed to bend it to various angles in order to see it clearly. It wasn't long before I snapped a couple of the pins and had to de-solder the damaged header and install a new one.

The second time, I used a female header, inserted a male header into it, and plugged the combination into my breadboard. Now if I break a pin I can simply replace the male header (or just the damaged part of it). However, I haven't had the problem again because I keep a few male headers bent to different angles and just swap the header when I can't see the display clearly. Naturally, this approach requires male headers that are long enough to be inserted on both sides (and bent on one side). If you need them, they're available on my website



■ FIGURE 3. 16x2 LCD stripboard layout.

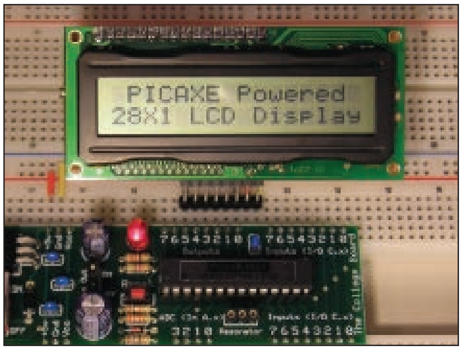
(**www.JRHackett.net/headers.htm**).

Our first stripboard will be for a 16x2 character LCD because the construction is a little simpler than that of the stripboard for the 8x2 LCD. The top and bottom stripboard layouts are presented in Figure 3, which includes all the necessary labels to facilitate the following discussion. In case the layout is too small to be useful, there is a larger version available on the *N&V* website at **www.nutsvolts.com** (look under "magazine > downloads") for downloading and printing. (This also applies to all the layouts presented in this installment of the Primer.)

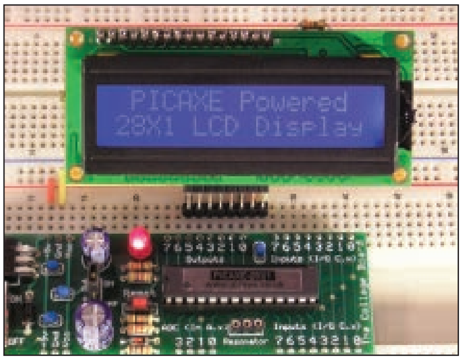
Figure 4 presents the Parts List, all of which are available on my website. The first thing you will notice is that the stripboard isn't near as long as the Hantronix 16x2 display. The first stripboard I constructed was that long (3.2 inches) because I thought I would drill holes to match the ones

ID	Part
C1	.01 mu F bypass capacitor
R1	10K Potentiometer
R2	* See Text
-	16-pin straight female header
-	8-pin (or two 4-pin) rt. angle female header
-	Jumper wire
-	Stripboard (21 traces, 1.4" long)

■ FIGURE 4. Parts List for 16x2 LCD stripboard.



■ FIGURE 5. Hantronics 16x2 LCD on Master Processor board.



■ FIGURE 6. “Brand X” 16x2 LCD on Master Processor board.

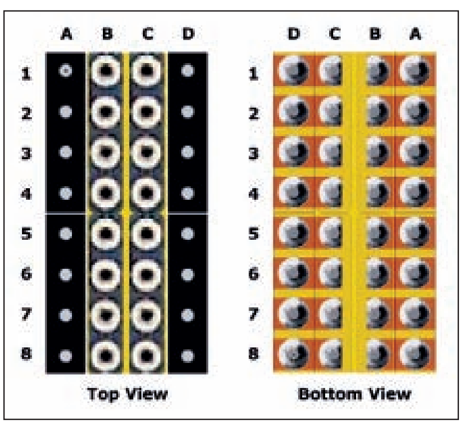
in the LCD display and bolt the two boards together. However, it’s six months later and I still haven’t done that! It turns out to be totally unnecessary — the 16 pin connectors (male on the LCD and female on the stripboard) hold them together perfectly well, and I like the flexibility of easily changing (non-backlit!) displays whenever I want.

Notice that the stripboard has the full 16 pin connector, so it can accommodate a backlit display (which requires pins 15 and 16 for the backlight). However, you can also insert a non-backlit 14 pin display (carefully avoiding pins 15 and 16) which I prefer for battery-powered projects. The smaller board size also has a second advantage: It perfectly matches the width of the stripboards available on my site, so minimal cutting is involved.

As you can see, the circuit is very simple. Essentially, it just routes the eight signals we are interested in (power, ground, Enable, RegSel, and the upper four data bits) from the LCD side to the breadboard side. In the layout, I use red wire for power, black for ground, and white for data lines; it just makes the layout easier to trace. Variable resistor R1 provides the contrast adjustment and R2 is the current-limiting resistor for the LCD backlight. As was discussed above, 27Ω works well for Hantronix backlit displays, but if you use a different brand you will need to do your own computations based on the information available in the LCD’s datasheet.

Two things are important about the eight pin, right angle female header on the breadboard side of the layout. First, the routing of the +5V (red) lines may seem unnecessarily convoluted, but there is a method to my madness! I have found over time that the right angle female header can start to bend from repeated insertions and extractions from the breadboard, so I like to include a wire that runs over the top of the header to securely fasten it to the stripboard. In this case, the power line served that function, but if none of the circuit wires are convenient, I always include an extra jumper across the top of the header (making sure to isolate it by cutting the appropriate traces).

Secondly, notice that the pin-out perfectly matches pins 19 through 26 of the PICAXE-28x1. As a result, the board can be directly inserted into a breadboard (via a double-ended male header) in line with pins 19 through 26. Figure 5 is a photo of a Hantronix HDM16216H-5-S00S non-backlit display inserted into my stripboard and connected to my 28x1 Master Processor board. In the photo, you can barely see the power and ground jumpers just behind the male header — don’t forget to include them.



■ FIGURE 7. Stripboard layout for 8x2 LCD adapter.

Before we move on to the software to drive our parallel LCD display, you will need to do one of two things: Using the layout presented earlier in Figure 3, construct the LCD stripboard circuit, or (if you prefer error prone circuits) wire up your LCD directly to pins 19 through 26 of your Master Processor circuit. If you decide to construct the stripboard circuit, I want to mention a recent development in my own construction process.

When I first discussed the cutting of stripboard traces between holes, I described how I used a small rotary hand tool for that purpose. I now use a small (1/8” x 2”) screwdriver that I purchased at a hardware store. I have sharpened it into a tiny chisel slightly less than 0.1” wide and use it to push into a trace between two holes (from both directions) to “pop out” a sliver of the trace. Using this approach, I now make no mistakes at all (other than cutting in the entirely wrong place altogether!), so at least for me, low tech is sometimes the way to go.

PARALLEL LCD TEST SOFTWARE

Once you have completed your circuit (either stripboard or rat’s nest), we’re ready to fire up our Master Processor and try it out. The software I used to test the board (LCD-parallel .bas) is too long to include here; and it’s available for downloading on the *Nuts & Volts* website. The program is very simple. All it does is display a message on the LCD to make sure the circuit is functioning correctly. Of course, the details of how it accomplishes this are fairly involved. A full explanation is in my earlier article (in the Feb. 2007 issue.)

All HD44780-based LCDs share a common set of commands to control their operation. For example, there are commands to implement either a four bit or an eight bit data interface, to use a blinking or underlined cursor, to scroll the display left to right or right to left, etc. Next time, we’ll explore some of the LCD pro-

gramming details, but if you want to get started on your own you can refer to your LCD's datasheet for a complete listing (or do a Google search for the words "HD44780" and "LCD").

One aspect of our test program requires explanation. In four bit programming mode, only the LCD data pins D7-D4 are used; pins D3-D0 are left disconnected. In order to simplify the software, the usual interfacing arrangement is to connect the LCD pins D7-D4 to the corresponding pins of the 28x1's output port. Since a data byte is output to the LCD in two four bit nibbles, the high nibble of the data byte is usually transferred directly, then the low is multiplied by four (to shift it into positions D7-D4) and transferred to the LCD.

However, for our stripboard circuit I wanted to keep the connector to the breadboard as short as possible so I decided to modify the usual connections so that the eight required lines were contiguous on the 28x1. Therefore, we are using the 28x1's D5-D2 pins to transfer the two nibbles (along with D1 for the Register Select line and D0 for the Enable line). As a result, we need to divide the high data nibble by four (to shift it right two positions) before sending it to the LCD, and then multiply the low data nibble by four (to shift it left two positions) before outputting it. That seemed like a small price to pay to simplify the physical connections, but as I was finishing the text for this column, it dawned on me that it would have been even simpler to put the four data lines in positions D3-D0 and use D5 and D4 for the LCD Enable and RegSel lines – duh! Since it only makes a difference of one additional instruction in the software, it really doesn't matter all that much. If you would like to redesign the stripboard circuit (and the next one, as well), feel free.

In any case, Figure 6 is another photo of the completed circuit in action, this time with a non-Hantronix backlit display. In the photo, you can see (protruding at the top) the 330Ω resistor that I used to replace the original 27Ω resistor so I don't blow up my nice blue display!

SIMPLIFYING THE PARALLEL INTERFACE FOR A 8x2 LCD

Next, we're going to do essentially the same thing for an eight character by two line LCD display. These little displays are great for small projects, but their 2x8 side-mounted connector does make it a little more difficult to construct a small stripboard, as we will soon see. Before we do that — and in case you don't feel like taking the time to build another stripboard — let's take a quick look at a super simple stripboard adapter. The layout is presented in Figure 7 and the completed adapter is shown in Figure 8. It consists of an 8x2 female header down the center and two 8x1 male headers reverse-mounted (pointing down) along the edges. As you can see, the board traces run horizontally and are each cut between the middle two holes.

You can use this simple little adapter to insert an 8x2 LCD directly into a breadboard so that its pins straddle the center of the breadboard similarly to an IC, providing a quick and easy way to experiment with these little LCDs. The down side (at least for our Master Processor circuit) is that the LCD is oriented in the wrong direction, so if you plan on doing much work with 8x2 LCDs you will probably want to construct our next circuit, as well.

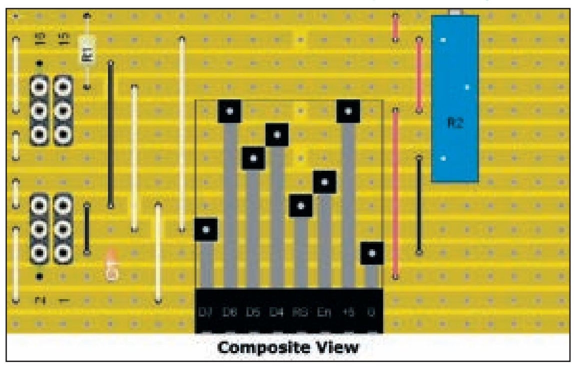
Figure 9 presents the stripboard layout for the parallel 8x2 LCD circuit and Figure 10 is the Parts List (also available on my website). The layout in Figure 9 probably won't make much sense until you read the following explanation. What makes this circuit more complicated is the fact that the LCD's connector runs vertically along the left side but the connector to the breadboard has to run

■ FIGURE 8. Completed 8x2 LCD adapter.

horizontally along the bottom. As a result, in a typical stripboard circuit whichever way you run the traces (up and down or side to side), soldering to one or the other connector requires excessive trace-cutting and the soldering is difficult.

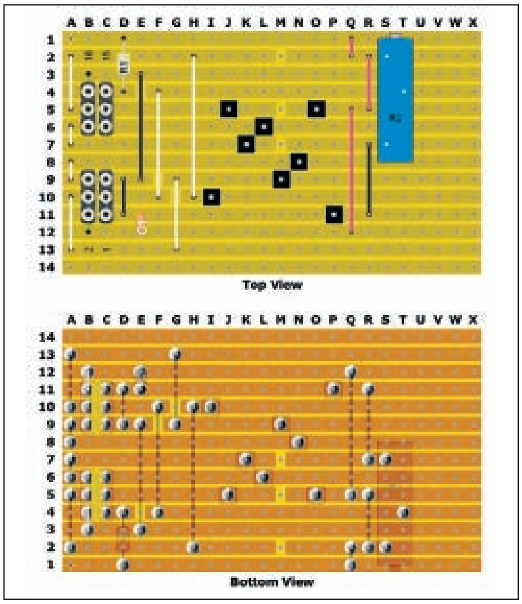
To solve this problem, I use an approach I call a SandwichBoard because it involves making a "sandwich" of two stripboards with male pin headers in the middle. The key is that the traces on the two boards run orthogonally to each other so that the vertical header easily connects to one stripboard and the horizontal header easily connects to the other one. If you look again at the composite layout in Figure 9, you'll see that the traces on the main (larger) stripboard run horizontally so that the female headers along the left side can easily be soldered to the board. (It's also worth noting that you can use a single 8x2 female header in place of the four three pin headers shown in

■ FIGURE 9. 8x2 LCD SandwichBoard layout (composite).

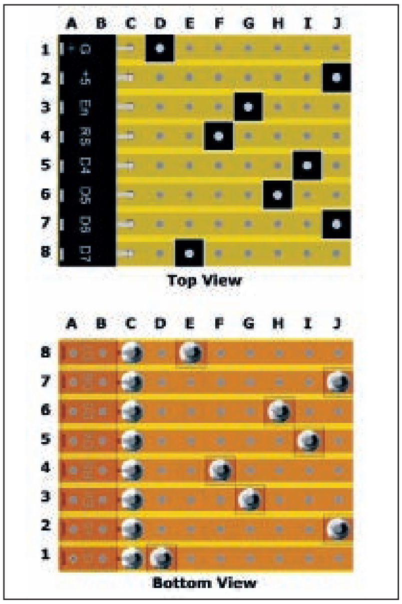


■ FIGURE 10. Parts List for 8x2 LCD SandwichBoard.

ID	Part
C1	.01uF bypass capacitor
R1	* See text
R2	10k Potentiometer
-	8x2 (or two 3x2) straight female header
-	8-pin (or two 4-pin) rt. angle female header
-	8 single male header pins
-	Jumper wire
-	Stripboard (14 traces, 2.4" long)
-	Stripboard (8 traces, 1.0" long)



■ FIGURE 11. 8x2 LCD SandwichBoard layout (lower board).



■ FIGURE 12. 8x2 LCD Sandwich Board layout (upper board).

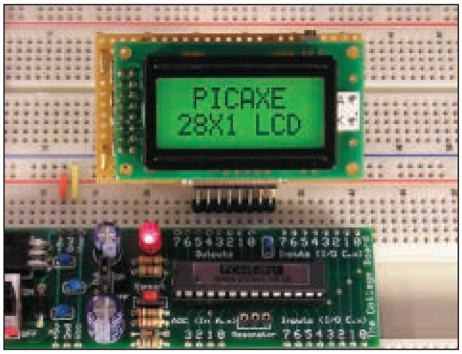
the layout by snipping off the four pins in the middle of the header so that it isn't soldered to the two traces that carry signals underneath.)

The second stripboard (the 8x10 cell rectangular area in the lower center of the main board) is oriented so that its traces (the gray stripes in the layout) run vertically. The eight black squares in this area are single pin male headers that are first inserted down into the main stripboard, then the top stripboard (with the eight pin right-angle female header already soldered in place) is added to the sandwich with its traces facing up. With a small spring-clamp holding the sandwich tightly together, the eight single pin male headers are soldered to both boards. Essentially, a SandwichBoard is similar to a double-sided printed circuit board (PCB) with the single pin male headers serving the same function as plated-through holes on a PCB — they each transfer a signal from one level to the other.

I realize that the above explanation may seem a little confusing at first, but if you refer to Figures 11 and 12 (which present the two layouts separately) and re-read the explanation it should be clearer. The important thing to keep in mind is that the upper stripboard is mounted upside-down, so that its bottom view is actually its top and vice versa (how's that for confusing?).

When the circuit is completed, the eight pins that connect to the 28x1 are actually in the reverse order to what is shown in the Top View of Figure 12. Again, that's because the upper board is upside-down in the sandwich. In other words, when the SandwichBoard is completed, the D7 pin is to the left and the Ground pin is to the right.

The SandwichBoard circuit is actually easier to construct than it is to explain — far easier than an equivalent single stripboard circuit. If you decide to build it, you can test it with the same software we used earlier. This may seem surprising, since an 8x2 LCD can only display half as many characters as a 16x2 display. The explanation is that most LCDs can store more characters than they can display (which is why display scrolling is possible). In effect, what you see displayed is a "window" showing only part of the stored text. If you are interested in display scrolling, check out the resources I mentioned earlier.



■ FIGURE 13. Hantronics 8x2 LCD on Master Processor board.

Figure 13 is a photo of a backlit Hantronix HDM08216L-3-L30S display mounted on the completed SandwichBoard. If you look closely, you can see two extra jumpers (along the left side) that aren't in the layout. That's because I found a way to simplify the layout after I had constructed my SandwichBoard. The 28x1 is running the same program we used earlier with the 16x2 LCD. As you can see, only the first eight characters of each line are displayed even though two 16 character lines were actually transmitted to the LCD.

ONWARD AND UPWARD

If all our projects were 28x1 based, parallel stripboard circuits would probably be all the hardware we would need to conveniently interface character-based LCDs. However, sooner or later we're going to want to connect a small LCD display to a PICAXE-08M. In that case, we would be out of luck because the 08M does not have enough I/O lines to get the job done and even if it did, its limited program memory would be significantly used up with a parallel LCD driver program. The answer to this problem is to "divide and conquer" — to dedicate an inexpensive 14M processor (which does have more than enough I/O lines) to the task of accepting a single line serial input from the main processor and using that input to drive the parallel LCD. Of course, we could simply purchase a commercial serial LCD (for $40 and up!) and be done with it. But we can also accomplish the same goal with a 14M ($4), a small parallel LCD ($5 to $8), and a stripboard circuit. Besides, we obviously like to tinker, and that's exactly the approach we will take in our next installment, when we develop two stripboard circuits to "serialize" our 16x2 and 8x2 LCD displays to further simplify their use in our upcoming projects. **NV**

SMILEY'S WORKSHOP

AVR MICROCONTROLLER: C PROGRAMMING - HARDWARE - PROJECTS

by Joe Pardue

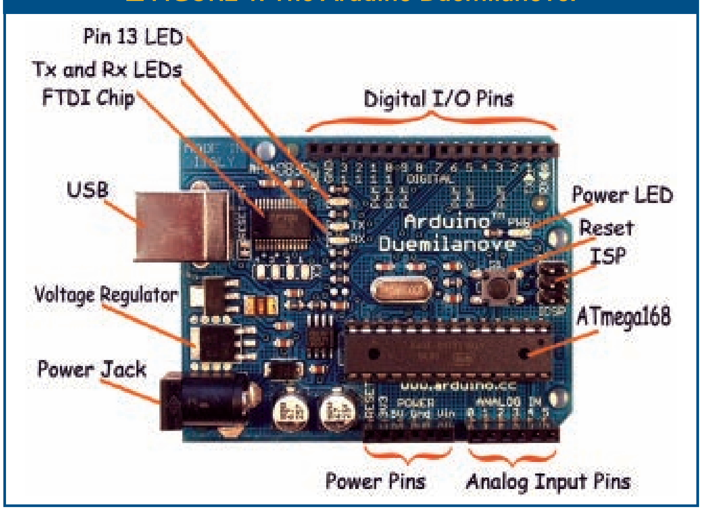
PART 9:
The Arduino Way

Follow along with this series! Joe's book & kits are available in our webstore at **www.nutsvolts.com**

If you have been following this series, then prepare for a bit of Workshop whiplash. Up to this point, we have learned how to program the AVR Butterfly using the C programming language with the WinAVR GCC compiler toolset and AVRStudio. Now, just when you think we would start learning more about the underlying AVR and doing more hardware oriented projects (like I promised), we are going to go off the rails, throw the gears in reverse, and accelerate backwards to the beginning so that we can learn an entirely new system: the Arduino Duemilanove (Italian for 2009).

This wasn't exactly according to plans, but as Robert Burns said: "The best laid schemes o' Mice an' Men, gang aft agley." And — while I can only hope that "gang aft agley," is what an 18th century Scotsman says when he means: 'go often astray' — just accept that I too am continuing to learn and occasionally plowing up a mouse in the process. One of the things that I learned in the midst of this Workshop series is that the Arduino is a darn good system for beginners and is even simpler than the Butterfly for the complete novice to use. I decided to insert a couple of Workshops to bring the reader up to speed with the Arduino and then get back on the rails and use both the Butterfly and the Arduino in subsequent workshops where we will — I promise (and this time I mean it) [really] — start learning more about the AVR hardware. And don't worry about all those brain cells you've used up learning C, the Arduino uses C. It just does a real good job of hiding that fact from the casual user.

■ FIGURE 1. The Arduino Duemilanove.



Restarting the Workshop

So, bear with me for this article since I am going to pretend that you, dear reader, wouldn't know a microcontroller if one bit you on the butt — it is not that I want to talk down to you — it is because the 'Arduino Way' was developed for total absolute novices.

Massimo Banzi begins his book, *Getting Started with Arduino,* "A few years ago, I was given the very interesting challenge: teach designers the bare minimum in electronics so that they could build interactive prototypes of the objects they were designing." He summarizes his philosophy of 'learning by tinkering' with a quote from **www.exploratorium.edu/tinkering**: "Tinkering is what happens when you try something you don't quite know how to do, guided by whim, imagination, and curiosity. When you tinker, there are no instructions — but there are also no failures, no right or wrong ways of doing things. It's about figuring out how things work and reworking them." Arduino provides a great toolset for designers, tinkers, and even some of us surly old engineers who sometimes just want to play with an idea.

The genius of Arduino is that it provides just enough access to get specific tasks done without exposing the underlying complexities that can be truly daunting for folks new at this stuff.

A Few Definitions

- **Sensor** — A computer-controlled mechanism that measures or detects events in the real world such as motion, light, or voltage. For example, an IR optical sensor used to detect the motion of a computer mouse.
- **Actuator** — A computer controlled mechanism that causes a device to be turned on or off, adjusted, or moved. For example, the devices that spin a DVD, move the sensing head, and turn the read/write laser on/off.
- **Micro (microcontroller)** — A single integrated circuit that contains a computer, memory, and peripherals used with sensors and actuators to provide control of real-world events. For example, an AVR such as the ATmega168 can be used to sense button presses, motor

rotation, and temperature, and use that input to control the voltage to the cavity magnetron (makes the microwaves) in a microwave oven.

- **Real World** — For our purposes, this is everything outside our micro and associated sensors and actuators, though to be completely honest, I gave up on trying to define 'real world' years ago.
- **Physical Computing (embedded systems)** — A combination of micro(s), sensor(s), and actuator(s) designed for some specific control function and 'embedded' into a specific device, usually requiring little human input. An example would be the air/fuel mixture control system in an automobile engine. This term is often used in contrast to a 'general-purpose computer' such as the PC or Mac, which can do a lot of different things and are designed for intense human interaction.
- **Sketch (program)** — A sequence of human readable text statements following the rules of a programming language that can be converted and uploaded to a micro providing instructions as to how it will make decisions about using its sensors and actuators.
- **Verify (compile)** — The process of converting a sketch to instructions suitable for the micro. The process provides feedback if the conversion cannot be completed due to errors.

■ FIGURE 2. Bogus security warning.

While using Arduino is relatively simple, it is built on top of some things that can quickly become complex if you dig a little below the surface.

Hardware Resources (see Figure 1):

- 14 digital I/O pins, six of which can be configured as analog output (PWM) pins
- Six analog input pins
- Pins are on female sockets that are easy to wire to a breadboard
- USB serial port with +5V bus power through a PTC fuse.
- Serial transmission and reception LEDs.
- May be switched to regulated external power socket.
- ATmega168 with a pre-programmed bootloader.
- ISP (In-System Programming) header.
- Reset button.

And Now a Word from our Sponsors ...

Smiley Micros and *Nuts & Volts* are selling a special kit — the Arduino Projects Kit — 2009, — which has a bunch of neat stuff that will help you train your Arduino to sit up, roll over, and chase bad guys. Sort of, anyway ... it actually has parts to help you learn how to use a micro-controller to: blink LEDs, read switches, talk to a PC, measure light, temperature, and voltage, AND other neat things [see the links at the end of the article].

BTW, the USB serial port on the Arduino uses the FTDI FT232R chip which was discussed in detail in the article "The Serial Port is Dead, Long Live the Serial Port' by yours truly in the June 2008 issue of *Nuts & Volts*. And, if you come to really like that chip you might want to get the book *Virtual Serial Programming Cookbook* (also by yours truly) and associated project kits from either *Nuts & Volts* or Smiley Micros. Be sure and check out the Design Cycle in this issue as it discusses the FTDI FT232R answer.

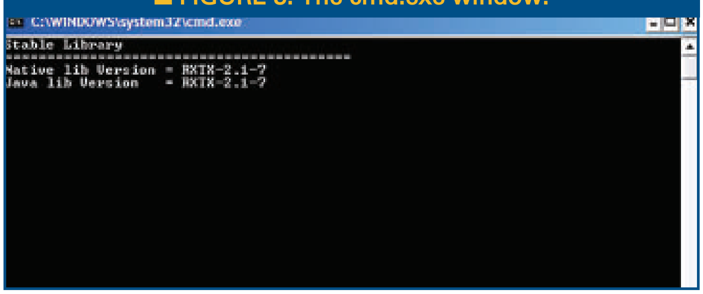
Genesis of Arduino

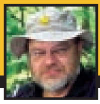
Verily in the olden days, artists wailed for lack of entry to the new land. And they were heard by great prophets who showed them a path: Processing. And lo, it came to pass that Processing begat Wiring which begat Arduino that, the time being ripe, begat a whole nation of xxx-duino derivatives. This, dear brethren, is the story.

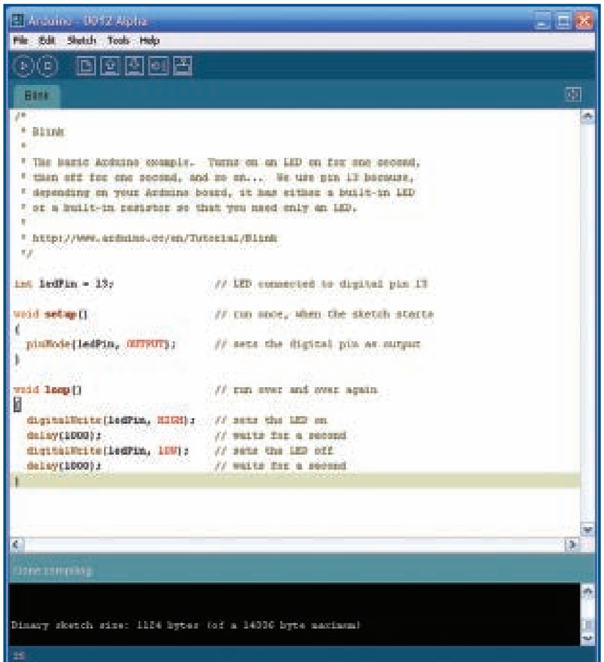
Processing

You have probably seen some of the cool (or annoying, depending on your viewpoint) graphic Java applets that bless (or infest) Internet browsers. Things like those 'too darn cute' rotating bouncing cubes with different pictures or messages on each face did show that you could use Java to build some very interesting graphic things, and artists took notice. The only problem is that artists tend not to be programmers and vice versa. Casey Reas and Benjamin Fry while in the Aesthetics and Computation Group at the MIT Media Lab took note of the potential for Java to be used by artists to do artsy stuff and decided to create a simpler interface that would be

■ FIGURE 3. The cmd.exe window.

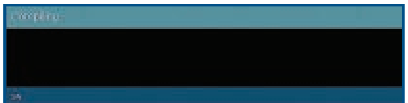




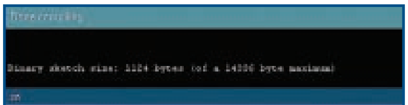


■ FIGURE 4. The Arduino Integrated Developers Environment.

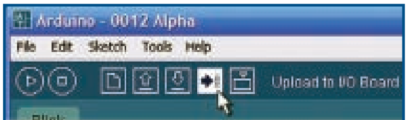
■ FIGURE 5. Verify the sketch.



■ FIGURE 6. Compile.



■ FIGURE 7. Done compiling.



■ FIGURE 8. Upload to the I/O board.

more artist-friendly. They developed Processing: a programming language, development environment, and online community [**www.processing.org**]. The syntax looks a lot like C (but then so does Java if you squint). The Arduino Integrated Development Environment (IDE) is derived from the Processing IDE.

Remember that Processing was designed for artists. It substitutes 'sketch' for 'program' and 'verify' for 'compile.' If you are at all interested in art, be sure and go to their website and click on the exhibition tab.

Wiring

Wiring was started by Hernando Barragán at the Interaction Design Institute Ivrea in Italy and builds on Processing to provide an 'electronics prototyping input/output board for exploring arts and tangible media.' The Arduino folks smash this mouthful into 'physical computing' and I'm temped to redub it 'playing with electrons' because it makes things so much easier than many earlier systems that the concept of 'play' is not out of the question. The Wiring board is based on the ATmega128 and the language has libraries built around that device's resources and tasks you might like to do with them (like blinking LEDs or monitoring a microphone). The good news is that this is a feature rich platform and the bad news is that all those riches cost money. So, enter the Arduino.

Arduino

Arduino is built directly out of Wiring except that it uses a more affordable board, and has its own online community. Massimo Banzi (**www.tinker.it**) thought up the name Arduino and — if the story is true — it was christened five minutes before the first board was to go into production. Massimo was on the phone with the PCB fabricator who wanted a name for the board and Massimo suggested the name of a bar that some of the developers once frequented. And while the name may be somewhat accidental, it is a masterstroke of Google-ability, especially compared to the names Processing or Wiring (try Google-ing the three and see what I mean).

Since this is all open-source, it didn't take long for lots of folks to make their own versions of the board and use the –'duino' in the name as if it was a valid suffix. This apparently irritates some Italians who note, for instance, that the board name Sanguino would be what an Italian would shout if he was bleeding. There was a bit of debate on the Arduino forum about PCB designs perhaps straying too far from the original concept and making it difficult to provide support so several of the originators copyrighted the name and allow its use for boards that pass muster. Naturally, a conspiracy theory rebellion occurred and some folks mounted their high horses and came up with the name Freeduino as a 'free' alternative (**www.freeduino.org**).

Arduino Quick Start Guide: The Arduino Integrated Developers Environment

You can download the Arduino software from **www.arduino.cc**. This article is based on release 0012 working on a Windows XP PC.

You can go ahead and click on ..\arduino-0012\Arduino.exe and see what happens; it might run on your system. In order to run the Processing IDE on my Windows XP machine, I have to click on the ..\arduino-0012\run.bat file. Windows doesn't like that, so it displays a security warning (Figure 2). To heck with Windows and its so-called security (like they would know security), just click 'Run.' This will open a 'cmd' window (Figure 3) and in a little while, Windows will run Java for you and display the Processing IDE (Figure 4).

The Blinky Program, urr ... Sketch

The Arduino Duemilanove has a built-in LED with a

resistor attached to I/O pin 13 (see Figures 1), so we will start with a program (okay, sketch!) to blink that LED.

The following sketch was copied from the Arduino-0012 menu:

File/Sketchbook/Examples/Digital/Blink and modified to better fit in the magazine.

```
/*
 * Blink
 *
 * The basic Arduino example.
 * Turns on an LED on for one second,
 * then off for one second, and so on...
 * We use pin 13 because, depending on your
 * Arduino board, it has either a built-in
 * LED or a built-in resistor so that you
 * need only an LED.
 *
 * http://www.arduino.cc/en/Tutorial/Blink
 */
// LED connected to digital pin 13
int ledPin = 13;

// run once, when the sketch starts
void setup()
{
  // sets the digital pin as output
  pinMode(ledPin, OUTPUT);
}

// run over and over again
void loop()
{
  // sets the LED on
  digitalWrite(ledPin, HIGH);
  delay(1000); // waits for a second

  // sets the LED off
  digitalWrite(ledPin, LOW);
  delay(1000); // waits for a second
}
```

We will discuss this later, but let's first run it and blink that LED.

Verify the Sketch (Compile the Program)

The Arduino folks also decided to call compile 'verify.' Instead of 'compiling the program' we are verifying the sketch' [artists ... go figure]. When you click on the button shown in Figure 5, the IDE uses the WinAVR toolset for the GCC C compiler, and if everything goes okay — meaning it compiles without error — you don't have to know what WinAVR is, how it works, or even that it is there. We'll look at the situation involving errors later.

After you click verify, you will notice some activity at the bottom of the Processing window. Figure 6 shows the bottom block of the IDE you will see 'compiling' and then the results of the compilation as shown in Figure 7.

Please don't ask me why they call it verify at the top of the IDE, but compile at the bottom. Hopefully, you got the message: "Binary sketch size: 1,124 bytes (of a 14,336 byte maximum" meaning everything is copasetic. [If you wonder why there are only a maximum of 14,336 bytes available when the ATmega168 has 16,384 bytes of memory, it is because 2,048 bytes are used for the bootloader.]

Uploading the Sketch to the Arduino Board

Next, we will 'Upload to the I/O board' as shown in Figure 8, meaning we will secretly use AVRDude to send the hex code using the USB serial port to the bootloader on the ATmega168 that will write it to memory. Though AVRDude is kept hidden, if you are curious, check out **http://savannah.nongnu.org/projects/avrdude**/.

Be sure and look at the TxD and RxD LEDs on the board right after you click the button so you can see them blinking rapidly in time to the flow of data between the Arduino board and the Arduino IDE. Sometimes it just helps to make things visible. The pin 13 LED should be blinking on and off now, once per second.

Well, that WAS easy, wasn't it? The Arduino Way is great for the intended audience: designers who want to know the bare minimum. But wait... *we* are readers of *Nuts & Volts*, and we want to know what is going on under the hood! So, next month we will learn how to use this neat Arduino board with the IMHO 'real' C programming language and the official Atmel software AVRStudio, and the semi-official WinAVR and AVRDude packages.

Look for information on the Arduino Projects Kit on the *Nuts & Volts* (**www.nutsvolts.com**) website. **NV**

ELECTRONET

For the ElectroNet online, go to
www.nutsvolts.com and click **Electro-Net**

■ BY LOUIS E. FRENZEL W5LEF

WIRELESS MADE EASY

New Kit and Wireless Protocol Simplifies Adding Wireless to Almost Any Product or Project

Wireless is not only one of the biggest buzzwords you hear these days, it is also a key feature of many new products. We all love wireless because it is so convenient and … well, duh, there are no cables or connectors to mess with. Think of your TV remote control, garage door opener, remote keyless entry on your car, and other wireless devices you use daily. Now you can bring that convenience and functionality to other projects.

Cypress Semiconductor recently released their CyFi low-power RF wireless kit that brings you everything you need to design and implement a wireless project. Also known as the PSoC FirstTouch Starter Kit, this package of hardware and software is an affordable kick-start to your own wireless gadgets. Here is a look at the new wireless protocol and the kit.

CYFI

It is amazing how many different wireless standards and protocols we have for short-range wireless applications. You have heard of most of them like Wi-Fi, Bluetooth, ZigBee, UWB, and the ISM (industrial-scientific-medical) products to name a few. There are lots more and Cypress has added a new one called CyFi. This new protocol and product is aimed mainly at applications that require only simple remote monitoring and control (see Figure 1).

You can monitor temperature or some other environmental condition at some remote location or you can control something with the press of a button or computer key.

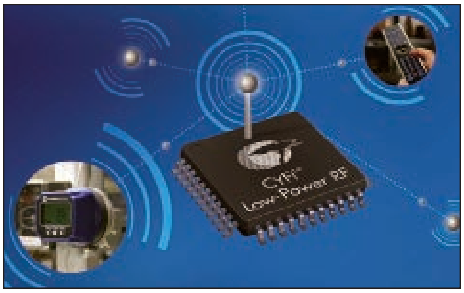
CyFi uses the ever popular 2.4 GHz unlicensed Part 15 frequency band from 2.4 to 2.483 GHz. Don't forget, Wi-Fi, Bluetooth, ZigBee, and a few others also use that band so it is plenty crowded with potential interference. But remember too that these are all short-range technologies so they should not really interfere with one another unless you have multiple wireless devices all in close proximity to one another operating at the same time. Even then, they may not interfere with one another due to technology differences.

What makes CyFi different is that is divides that spectrum into 80 1 MHz wide bands or channels. The technology provides what we call "frequency agility," meaning the ability to move around and change frequency to respond to and avoid interference. The CyFi chip monitors activity in that band and assigns itself a frequency no one else is using.

The CyFi radios use two different modulation methods. For best performance and link reliability, it uses direct sequence spread spectrum (DSSS) with GFSK modulation. The chipping code is 32 bits and the chip rate is 250 Kchips/sec. That gives a maximum data rate of 1 Mb/s. The radio is designed to downshift to a lower speed — 250 Kb/s or 125 Kb/s — if the range is too great or interference too severe.

At the lower speeds, the radios use plain old GFSK. In some cases, the radio will discard the straight GFSK and shift to DSSS to maintain contact. The DSSS provides coding gain of nine to 13 dB over the GFSK alone improving link reliability.

Transmit power also adjusts to the prevailing conditions and can be anywhere from -5 dBm to +4 dBm. You can get up to +20 dBm with an external power amp. The receiver sensitivity is -97 dBm and includes received signal strength indication (RSSI). The cool thing about the radio is all



■ FIGURE 1. Cypress Semiconductor's CyFi is a proprietary wireless protocol and CYRF7963 transceiver chip designed for short-range, low power remote monitoring and control applications.

this adjustment is automatic. It looks for interfering Wi-Fi or Bluetooth signals, switches frequencies to avoid them, then adjusts power output and data rate to ensure a reliable transfer of data. The Cypress designation for this transceiver chip is CYRF7963.

The CYRF7963 is designed to work with Cypress' PSoC (Programmable System on a Chip) embedded controller, an eight-bit device of Cypress' design. Its key feature is that it comes in a variety of models with differing memory configurations and lots of on-chip analog and digital I/O, making other peripheral chips unnecessary.

A typical configuration uses 32K of Flash memory, 2K or SRAM, a 32-bit accumulator, an 8x8 multiplier, and an I^{2}C interface. Some of the available analog I/O circuits are ADCs (up to 14 bits), DACs, comparators, amplifiers, timers, and counters, PWM output, as well as SPI and UART interfaces. Some of the amplifiers even have programmable gain.

CHECKING OUT THE KIT

You can buy the kit right off the Cypress website; you can see the hardware in Figure 2. The largest piece is the PC dongle (also called by various other names like PC hub or PC bridge). It contains the CYRF7963 transceiver and two of the PSoC chips: one to operate the application that you will program and the other to handle the programming. This board contains the USB connector that plugs into your PC or laptop. It comes in a protective clear plastic housing. At the end of this module is a 16 pin connector used to connect to some of the other modules. Incidentally, this module also has an embedded antenna so it is fully self-contained and gets its power via the USB port.

A second module is the RF expansion board. This is another full transceiver with one other PSoC embedded controller to run the specific application. This is the module you will use in your remote project. It talks to the PC dongle over a range up to several hundred feet — the exact distance depending on the environment. This board actually lets you bump the output power to as high as +20 dBm for longer range. With full power and a direct line of sight, the range can be as much as a quarter mile.

Other features of the board are a thermistor for use in a temperature monitoring application and several pushbuttons and LEDs. This board has a matching 16 pin connector that plugs into the PC dongle for programming or one of the two battery power boards provided.

Of the two battery boards, one of them holds two AAA cells for power, the other holds a coin cell. Both have on/off switches to power down when not in use. The connector matches up with that on the RF expansion board.

The final board in the kit is called the multifunction board. It has a bunch of stuff on it including a three-color LED indicator, a thermistor, a light sensor, and a buzzer. This board features Cypress' Capsense proximity sensor and slider. With this hardware, you can implement a wide variety of wireless monitor and control applications.

■ FIGURE 2. Cypress Semiconductor's PSoC FirstTouch Starter Kit includes all you need to create wireless projects. It includes a PC hub with a USB interface to a PC (on the right) and an RF expansion board (center) — both full transceivers. A multifunction board (left) provides added LEDs, pushbuttons, and proximity sensors for other I/O experimentation. An AAA battery power board (foreground) and coin cell battery board (not shown) provide the remote power. Full software and documentation is on a CD.

The kit also comes with a CD full of software and documentation. Development tools include the PSoC Programmer, the PSoC Designer and the Sense and Control Dashboard — a graphical device used for input and output management and display.

The PSoC Programmer is a standard integrated development environment common to any embedded controller. You can program the PSoC devices in C or assembler. The PSoC Designer is a graphically based development package that lets you create your own wireless design by on-screen manipulation of icons and symbols. So you can do this without knowledge of programming or the protocol.

There are lots of engineers who want to add wireless to their designs but are not software geniuses. This solves the problem, but it is not without its own challenges. Learning any new software is always a time-consuming and sometimes frustrating endeavor, as I found out.

As for the Dashboard, this is a GUI that gives you some graphical input and output options for display. The documentation is a huge 100+ page manual you will probably want to print out as I did.

PLAYING WITH THE DEMOS

The kit comes with several pre-programmed demos and examples. The first one demonstrates the use of the multifunction board powered by the AAA cell board and shows how the CapSense slider works. Using your fingertip, the sensor detects positions on the board and lights up the LEDs from red to green to yellow as you move your finger.

Next, you demo the wireless boards. Plug the PC Hub into the PC and program it using the PSoC software and Programmer. Then, program the RF expansion board. This is done by

plugging the RF board into the PC hub and again using the PSoC Programmer to load the software into the Flash memory. Next, you separate the boards and "bind" them, creating a simple peer-to-peer network. Finally, you call up the Sense and Control Dashboard and view how the temperature data is captured and plotted on a graph. It really is wireless made easy.

Some of the other demos and examples include light, touch, and temperature sensor actions. The light sensor demo shows the multifunction board being used to alter the brightness of an LED based on the feedback brightness of the ambient light picked up by the sensor. The proximity demo shows the use of the proximity detection feature on the multifunction board. The multifunction board is also used in a remote temperature sensor demo.

There are several other proximity, light, and temperature demos that further explain what you can do with this kit. All of the original code is supplied so you can use these to create variations of your own without reinventing the wheel.

FINAL THOUGHTS

I didn't have the time to conjure up my own application and program it as I wanted. I will be doing that later as time permits. I did get a good sense of what you can do with the Cypress CyFi kit thanks to all the demos and examples. Here are a few observations:

• The wireless works great. Very reliable even under horrible environmental conditions. This is probably because the data rate is low and the modulation is robust. As always, you will need to experiment to determine the maximum range for your application.

• The documentation is good but not great. For a beginner, it leaves you hanging in places. For some of the demos, I needed help. Good thing the Cypress website is there with more information than you can ever use (**www.cypress.com**).

• If you are not an embedded programmer, you may be intimidated by this kit. If that is the case, use the PSoC Designer software that lets you program the kit with the iconic software. I did not do this myself, but it looks easy enough once you go through the documentation.

• This kit is not for beginners. You really need to be embedded oriented. The kit is targeted for embedded developers who are not wireless-wise. If you have been playing around with embedded controllers of the 8051, 68HC11, or PIC type, you should do just fine. Just remember, today practically every electronic product contains an embedded controller surrounded by the I/O hardware that implements the application. Most of the design is in the software. Get used to that as it is just the way it is. These days, electronic experimenters are programmers just as much as they are hardware hackers. **NV**

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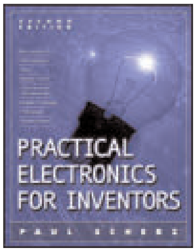

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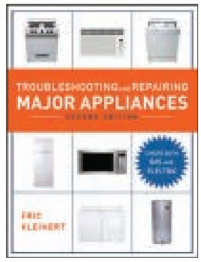

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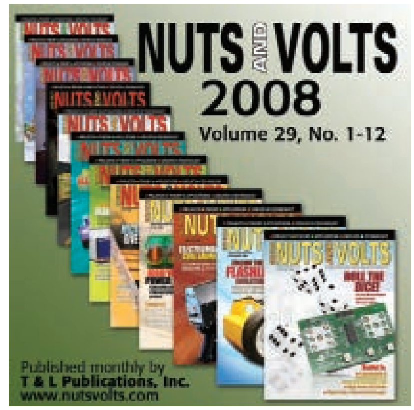

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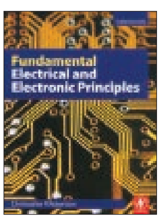

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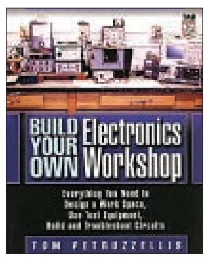

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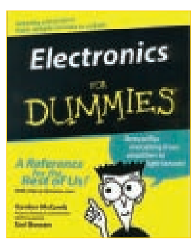

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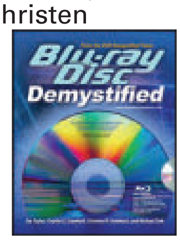

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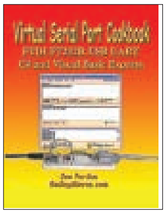

Virtual Serial Port Cookbook
by Joe Pardue
As talked about in the *Nuts & Volts* June issue, "Long Live The Serial Port"

Kit **$69.95**

Book **$44.95**

This is a cookbook for communicating between a PC and a microcontroller using the FTDI FT232R USB UART IC. The book has lots of software and hardware examples. The code is in C# and Visual Basic Express allowing you to build graphical user interfaces and add serial port functions to create communications programs.

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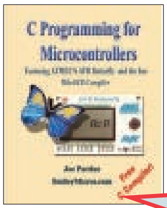
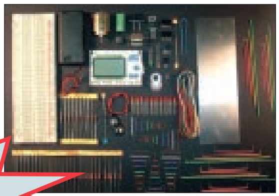


From the Smiley's Workshop C Programming for Microcontrollers
by Joe Pardue



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See Joe's all new Arduino Project Kit Page 62

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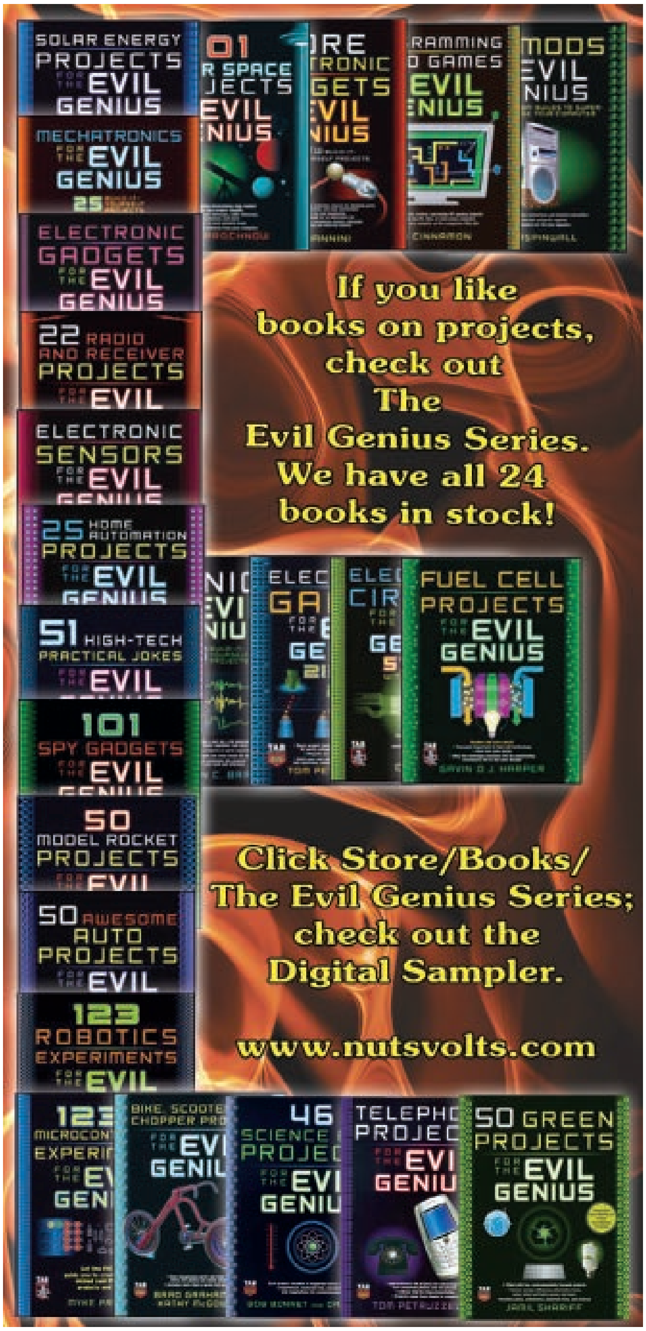

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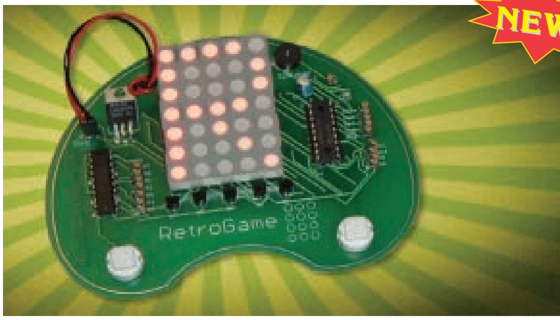

As seen in this month's issue by Eric Rothfus.
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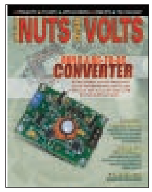
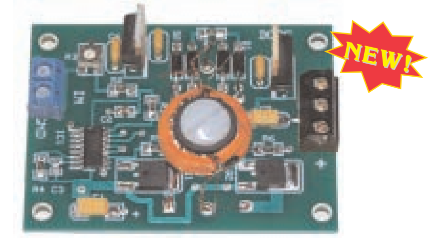


As seen on the March 2009 cover



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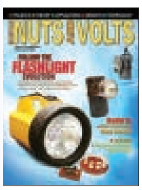

As seen on the February 2008 cover

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As seen on the December 2008 cover.

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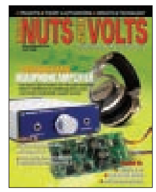

Need to regulate your power output? Take a look at this new and improved regulator.
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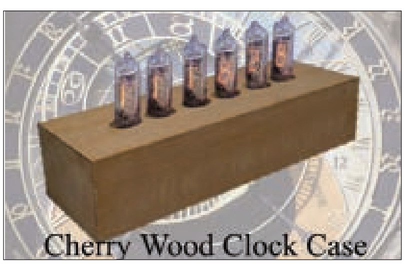

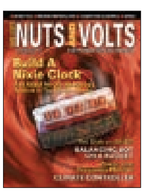

October 2006

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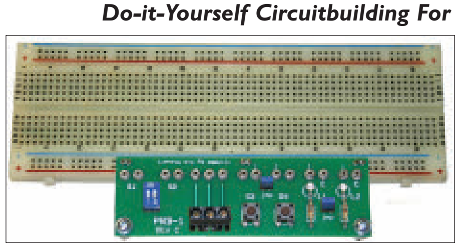

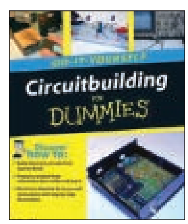

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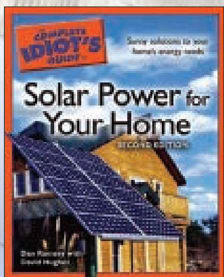
ALTERNATIVE ENERGY SECTION

The Complete Idiot's Guide to Solar Power for Your Home

by Dan Ramsey / David Hughes

Publish Date: May 2007



The perfect source for solar power — fully illustrated. This book helps readers understand the basics of solar power and other renewable energy sources, explore whether solar power makes sense for them, what their options are, and what's involved with installing various on- and off-grid systems.

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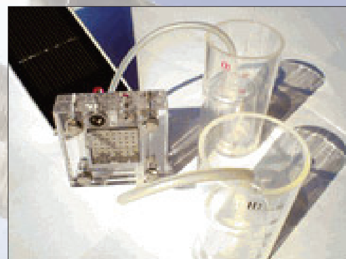


The Solar Hydrogen Generation Set includes a solar cell, a PEM reversible fuel cell, as well as oxygen and hydrogen gas containers. The set only needs pure water to create hydrogen and produce electricity. Perfect for science labs, classroom use, or demonstration purposes.

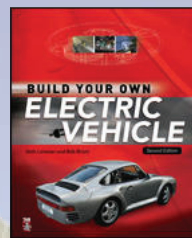
$67.00

Build Your Own Electric Vehicle

by Seth Leitman, Bob Brant

Publish Date: October 10, 2008

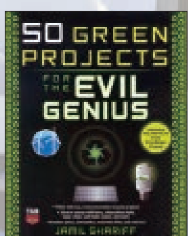
Go Green-Go Electric! Faster, Cheaper, More Reliable While Saving Energy and the Environment!



This comprehensive how-to goes through the process of transforming an internal combustion engine vehicle to electric or even building an EV from scratch for as much or even cheaper than purchasing a traditional car. The book describes each component in detail---motor, battery, controller, charger, and chassis---and provides step-by-step instructions on how to put them all together. **$29.95**

50 Green Projects for the Evil Genius

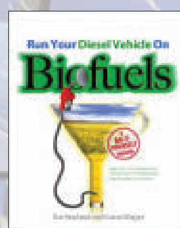
by Jamil Shariff



Using easy-to-find parts and tools, this do-it-yourself guide offers a wide variety of environmentally focused projects you can accomplish on your own. Topics covered include transportation, alternative fuels, solar, wind, and hydro power, home insulation, construction, and more. The projects in this unique guide range from easy to more complex and are designed to optimize your time and simplify your life! **$24.95**

Run Your Diesel Vehicle on Biofuels A Do-It-Yourself Manual

by Jon Starbuck, Gavin D J Harper



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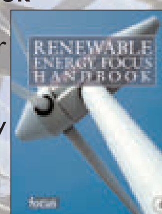

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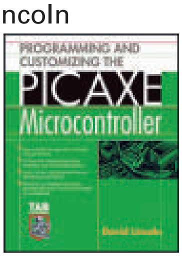
SPECIAL OFFER

Programming and Customizing the PICAXE Microcontroller

by David Lincoln



Here's everything you need to harness the power of PICAXE, the inexpensive yet versatile chip that's taken the electronics community by storm. This beginner-friendly guide from IT pro and PICAXE expert David Lincoln shows you just what Revolution Education's PICAXE can do and helps you make it do it!

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READER FEEDBACK

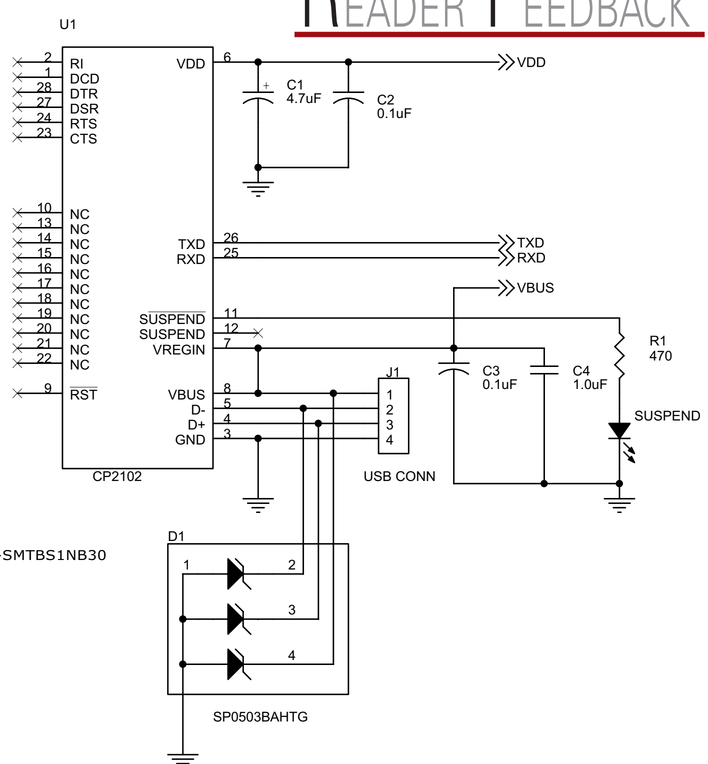
continued from page 10

there because of the separable power supply needs of the other interfaces. In summary, if you make a USB powered microcontroller controlled device that uses either five volts or 3.3 volts derived from the USB port at less than 100 mA for 3.3 or 500 mA for 5V, you only need the CP2102 and three external parts. I just thought you would like to know this for future reference.

Barry Mead (Independent Design Engineer)

Response: Thank you very much for taking time to read the Design Cycle column. They say great minds roll in the same gutter. :-) Your insight on the CP2102 and CP2103 is right on. In fact, as my USB travels in Design Cycle continue, I introduce the CP2102 with the three parts you mention. I added a couple of filter caps on the VREGIN line and threw in a SUSPEND LED for kicks. Here is the schematic.

Thanks again for reading Nuts & Volts and sharing your knowledge. Fred Eady



NOTES:
1. USB CONNECTOR-MOUSER 806-KUSBX-SMTBS1NB30
2. C1 - DIGIKEY 511-1471-1-ND
3. C4 - MOUSER 80-C0805C105M4R
4. ALL LEDS 1206 SMT PACKAGE
5. ALL RESISTORS 0805 SMT PACKAGE
6. ALL CAPACITORS 0805 SMT PACKAGE

TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams should be computer generated and sent with your submission as an attachment.*

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To be considered, all questions should relate to one or more of the following:

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2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

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- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions are subject to editing.

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- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.
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- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

Stereo TV Volume Regulator

On several cable channels, commercials are much louder than normal programming, or the volume level changes annoyingly during a program. Does anyone have a circuit that can be built into a stereo TV to provide an "AGC" function? Ideally, it would be installed by cutting into the low-level L and R audio inputs to the power amp IC (analog signal) and inserting this circuit in-line. Also, it would be great if it could be powered by an available supply in the TV (generally 12V).

#4091 **George Nutzul**
West Hurley, NY

DC to AC Inverter for the Grid

Does anyone have a solution with a schematic on how to sync a modern inverter like those from Harbor freight — say their 700 watt model — to the grid. (Very important for anyone working with solar and the green problem!)

#4092 **Tom Oliver**
Dewey, AZ

Linear Generator

I need an efficient linear power generator. Any ideas how to make one? Perhaps using a voice coil style or moving magnet in a coil/tube setup. It must be as efficient as possible and able to handle direction and voltage polarity change so that electrical output is maintained at 12 VDC or as close as possible. It needs to work with a push rod with a throw of 3-6 inches.

#4093 **Jay Steele**
Fort Myers, FL

Adding USB

I want to add a USB port to a CD boombox. How complicated of a process am I looking at?

#4094 **Mark**
Hawley, PA

Digital TV Conversion

Has someone come up with a design for a digital TV converter which can be programmed like a VCR for taping when I'm not around?

Ideally, it would support two lines: one for the VCR and one for the TV. But this isn't a requirement.

#4095 **Max Gage**
Seattle, WA

LM3915 Setup

I'm trying to build an LED display to show the position of a remote arm. I am using the LM3915 in the dot mode to drive the 10 LEDs. The voltage divider to establish the position of the arm is my problem. I have linked a 10K pot to the arm via a direct link. The arm moves the pot about 90-100 degrees of its travel limits.

This unit is being powered by 12V which is also available for use in the power divider circuit for the input. I have placed in series with the 10K pot

another 5K pot as a method to refine the scale of the output. I've had no luck setting it up so that when the arm is at one limit, the #1 LED is on and when at the other limit (approx. 95 deg of travel on the pot), the #10 LED is on. I would also like the display LEDs to be adjustable in brightness, as well.

#4096 **Charlie Willwerth**
Saint Augustine, FL

Is there an up-to-date schematic or project to convert RGB or Composite video signals to VGA (or SVGA, XGA, etc.) and vice versa? I'd like to incorporate this into a few home projects. I don't want to buy one, just build one!

#4097 **John Procida**
Virginia Beach, VA

>>> ANSWERS

[#11083 - November 2008]
Power For Hughes Satellite Dish

I was given an HN7000S dish and modem. The DC in is an eight-pin DIN but I do not have the power supply or pinout to make it myself.

Going to Reference 1 below, the part number 1500081-0001, P/S (power supply) is listed as 45 watt; pins 1, 2 as +6.5V 0.8A; pins 6, 7 as 19.5V 2.06A; and pins 3, 4, 5, 8 as return. The 1500081-0001 P/S is listed in the *Hughes Remote Terminal Installation Guide*, which can be found at Reference 2. This *Guide* will help you with the installation of the Hughes satellite dish. Though, it says little about the P/S other than the part numbers.

References:

[1] http://ivainc.net/Parts.html
[2] www.satsig.net/bentley-walker/hn7000s/HN7000S-HN7700S-Remote-Terminal-Installation-Guide.pdf

Dennis Crunkilton
Abilene, TX

[#12081 - December 2008]
Solar Battery Charger

I'm looking for a circuit for a microcontroller based solar battery charger that can charge four or eight NiMH rechargeable AA batteries.

The answer to your question is in "Q&A" with Russell Kincaid, *Nuts & Volts*, July 2007. See "NIMH Battery Charging," Figure 13 schematic and Figure 14 PICBASIC program listing. The charger uses a PIC12F675 microcontroller.

Kincaid's design charges a 2.5 AHr NIMH "D" cell at 750 mA for five hours. This is three times the 250 mA current for a C/10 rate over a period of 15 hours. I will assume that your NIMH "AA" cells are rated at 1.8 AHr. Thus, the C/10 rate is 180 mA over 15 hours. Three times that is 540 mA over five hours. Kincaid gives R1, the resistor setting the charging current for the 317 regulator, as R=1.2/I. His charging resistor for 750 mA is R=1.2/0.75=1.6 ohms. You should change R1 to R=1.2/I=1.2/0.54=2.22. A 2.2 ohm, 1W resistor is a close standard value. If you have 10 ohm 1/4W resistors on hand, parallel five of them for 2.0 ohms.

Dennis Crunkilton
Abilene, TX

[#120812 - December 2008]
On Air Digital TV

After the switch to digital TV, can I use the same antenna I am using now for analog reception? It seems that everyone thinks that all the signals will be using the UHF band and are selling UHF antennas. Is this true or will some of the stations keep the frequencies they are using now? Is there a frequency listing of the stations after the change-over in February? I was under the impression that the VHF/UHF antennas that are being used now would work for HDTV, but I get conflicting advice regarding this.

While the majority of broadcasters will be using the UHF band, not all will. Chances are the antenna you use now will continue to serve after the switch to digital.

There is a good article on the Crutchfield website at **www.crutchfield.com/learn/learningcenter/home/antenna.html** that provides useful information and links to other sites, most notably the Consumer Electronics Association/National Association of Broadcasters **AntennaWeb.org** website. Here you will find the analog and digital station listing for your area.

This will help reduce your confusion and get the best possible HDTV reception.

Morgen Van Sycle
via email

[#10910 - January 2009]
No On-Screen Keyboard Please

I have Windows Vista Home Basic Edition installed on my laptop. How do I stop from ever seeing the on-screen keyboard?

It sounds like Michael's computer has the default installation of Vista. If so, then the TabletPC components are installed. Use the 'Turn Windows features on or off' control panel applet to remove the TabletPC components which will, in turn, remove the tablet input panel (TIP).

MJ
via email

[#1097 - January 2009]
SSR

I would like to know how to calculate input resistance and design with a solid-state relay used as a switch.

#1 Solid-state relays come in a wide variety of styles for different applications, such as DC/DC or DC/AC, to mention a few. Start with the datasheet for the device you intend to use. Most have an infrared LED on the input side and a resistor to adjust the current. Keep in mind that you need a minimum current to turn the relay on reliably; more is almost always better, as long as power dissipation is reasonable. LED efficiency is better at low temperatures; current increases as well, since the LED forward current drops by about 2 mV per deg C. LEDs do age. This is a function primarily of temperature, current, and on time.

The quality of your input signal is also a consideration; clean on and off signals with a fast on/off transition is best. Long lines can pick up stray signals distorting the signal, and should be avoided. Some SSRs therefore have a Schmitt-Trigger input and mimic conventional relays with

pick-up and drop-out voltages, but some have awful temperature dependence.

For further information, please see Sharp Electronics Corp. *Introduction to Optoelectronic Devices*, Chapter 1 – Basics, Chapter 8 – Use of Solid-State Relays (SSRs), and Avago (spin off from Agilent/HP) *Technologies Optocoupler Designer's Guide* (both available on the Internet). Jameco, Mouser, and Digi-Key have easy access to the datasheets of devices they sell.

Walter Heissenberger
Hancock, NH

#2 I cannot give you a definitive answer for your particular SSR without knowing the part number, tying to a corresponding datasheet. However, we can look at the characteristics of a specific family representative of many SSRs for a general answer. This may (or may not) be applicable to your part. A datasheet for the OPTO-22 series of SSRs is located at **www.opto22.com/documents/0859_Solid_State_Relays_data_sheet.pdf** (see pg. 13). This is a DC controlled device on the input side, and capable of thyristor switching many amps of AC on the output side. It is contained in a rectangular package less than two inches per side. Does this roughly describe your device?

Page 13 says that the internal resistor is 1,000 ohms in series with an LED dropping 1V. We may apply between 3V and 32V directly to the input terminals, fully switching the device. We do not need to know the current because signal pickup voltage is listed as 3 to 32 VDC allowed. However, the current, IC, with 3 VDC control voltage is:

IC = (3 - 1)/1000 = 0.002 A (2 mA)

The current with 32 VDC control voltage:

IC = (32 - 1)/1000 = 0.031 A (31 mA)

For a DC control voltage, VC, higher than 32V, an external current limiting resistor, Re, is required. To limit the currrent to, say, 2 mA, Re is:

Re = 500 (VC - 3)

Again, see page 13 for details.

Dennis Crunkilton
Abilene, TX

[#2091 - February 2009]
Meter Conversion

I am building a project that uses a 0-100 UA meter. Can I purchase a DATEL/MURATA 0-199.9 UA digital meter (LED) and use it in place?

#1 The first thing is to check for a difference between the sensing element resistance in the analog and digital meters. An analog meter often gets by with a lower voltage drop than a digital meter due to the digital's assumption that a .1 or .2 volt drop across an internal resistor is okay. This is sometimes a "gotcha" in low voltage high current (i.e., single cell or two cell designs). A workaround might be a low cost panel meter and a sensing cicuit from Analog Devices, Linear Technology, Maxim, National, etc.

Earl Bennett
via email

#2 Yes, a digital meter could replace an analog meter, but there are some things to consider.

1. Does the current fluctuate? Digital meters are hard to read while changing, and an analog meter makes the rate of change easier to perceive.

2. Is there a high-frequency component (i.e., pulsating DC or RF modulation)? Some digital meters do not display accurate results under those conditions.

3. What is the internal resistance of the meter? If the replacement you select has the same or lower resistance, it should be okay, but if it is much larger, the voltage dropped across it might be significant in a particular circuit. (In all likelihood, that would not be a problem.)

Bart Bresnik
Mansfield, MA

#3 The answer is generally yes unless the project is dependent on the series resistance of the analog ammeter. The resistance of an analog meter can be measured by taking a battery (say 9V) and a fixed resistor higher than R=9/200e-6 all in series with the analog meter. Start with the resistance at the highest value and reduce until the current read on the analog meter is 1/2 of full scale. This is the internal resistance of the meter. That info can also come from the datasheets.

The digital ammeter is usually a shunt ammeter anyway, and a voltage is measured across a fixed resistor and scaled to read current. You may have to modify the circuit slightly or add resistance to the circuit. You cannot subtract resistance.

Ron Dozier
Wilmington, DE

#4 The Murata DCA-20PC-1-DC1-RL-C could be wired into your application in place of the analog meter. The extra power supply might not be required if the negative meter terminal is connected to the negative terminal of the system power supply and is within the range of 5-40 VDC. If there is not a direct connection between the meter and power supply negative terminals, yes, your isolated power supply will be required.

Denis Kuwahara
Port Orchard, WA

[#2092 - February 2009]
USB Speakers

Can a USB speaker — like a Harmon Kardon iSub 2000 — be rewired to use a regular audio input while still using the built-in amp?

The answer to this question would be technically, yes. However, there would be quite a lot of modification involved. Most, if not all USB speakers do not receive an analog audio stream from the PC — rather, they are installed with driver support as an external audio device. They receive a PCM audio data stream through the USB port and use an internal D/A converter to produce the analog audio signal. This is then amplified by an internal preamp and audio amp that utilizes the DC voltage available from the USB port. You would have to find the proper place between the D/A converter, preamp, and audio amp to inject your audio (not to mention supplying the unit with a separate DC source). It would be far more cost (and time) effective to just purchase a set of powered speakers with a line level input.

Brian Conn
Fort Wayne, IN

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ESD Safe, CPU Controlled, SMD Hot Air Rework Station

What every shop or lab needs to deal with todays SMD designed circuit boards. O.E.M. manufactured just for Circuit Specialists Inc., so we can offer the best price possible! A multi-technology assembly and repair station. A wide selection of nozzles are also available.

- CPU Controlled
- Built-in vacuum parts handling wand
- Air Pump: Diaphragm special-purpose lathe pump
- Capability: 23L/min (Max)
- Temperature Range: 100°C~480°C/212°F~896°F
- 15-Minute Stand-By temperature "sleep" mode
- Power:110/120 VAC, 320 W maximum

Item # **CSI825A++**

Big Sale! Inventory Reduction

$99.00

OVERSTOCK SALE CSI-2901 LEAD Free Soldering Station

Compatible with all lead-free alloy solder and standard solder. Excellent thermal recovery without a large increase in tip temperature. Utilize an integrated ceramic heater, sensor, control circuit and tip for greater efficiency, along with a highly dependable 24V output transformer. The effortless replacement of soldering tips makes for quick changes and the optional shutdown setting turns the unit off after 30 min. of idle time. Various tips are available at our Web Site!

Item # **CSI-2901**

- Power Consumption: 70W
- Output Voltage: 24VAC
- Temp Range: 392-896°F

Reg Price $59.00 **$39.00**

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage & current outputs. Short-circuit & current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance & long life. All 3 Models have a **1A/5VDC Fixed Output** on the rear panel.

Item #:	Price 1-4	Price 5+
CSI3003X-5 0-30V/0-3A	$119.00	$112.00
CSI5003X5 0-50V/0-3A	$127.00	$119.00
CSI3005X5 0-30V/0-5A	$129.00	$122.00

SMD Resistance, Capacitance & Diode Checker

NEW ITEM

A very convenient & small tool for testing SMD (Surface Mount Device) components, for example chip type resistors, capacitors and diodes. In addion it has a continuity function. Complete with storage case, battery and extra tip set.

- Auto Scanning Mode/Auto Range
- Display 3 2&3 digit (3000 counts)
- Over load protection
- DATA HOLD Function
- `FUNC' key manually holds the current reading
- Low battery indicator
- Auto Power Off
- Power Supply: 3V Lithium Battery (CR2032) 1pc

Resistance Ranges:
300 3K 30K 300K 3M 30M Ohms

Capacitance Ranges:
3nF 30nF 300nF 3uF 30uF 300uF 3MF 30MF

Capacitance & Diode Check:
Buzzer sounds when <30 Ohms

Item # **MS8910**

$29.95

Temprature Controlled Reflow Oven

NEW ITEM

FUNCTIONS and FEATURES

- Microprocessor-controlled equipment.
- Direct PCB temperature measurement, improves accuracy and lessens damage or distortion.
- Five (5) temperature and time control points with automatic slope adjustment. Configurable to suit different solder paste and circuit boards.
- Two (2) default profiles suitable with most common solder paste specifications.
- Quick and easy resetting of control points for precise tuning of reflow profiles.
- Built-in safety feature of industry standard 0.01°C/s to 3°C/s rising slope.
- Fully digital panel controls and read-out of time and temperature for monitoring and ease of use.
- Highly compatible with lead-free applications.
- Valid Solder Area: 8.274 in x 7.486 in

Item # **HHL3000**

$949.00

ESD Safe SMD & Thru-Hole Rework Station

An SMD rework station & soldering station in one handy unit! Perfect for shops & labs dealing with todays SMD board designs. Comes with an ESD safe soldering iron and a Hot Air Wand with 3 Hot Air Nozzles. A wide range of nozzles are also available.

Big Sale! Inventory Reduction

Item # **CSI906**

$99.00

New Item!

Close Focus Small Spot Size Infrared Thermometer TN01U

ZyTemp

Featuring spot-on, dual-laser aiming, the TN01U close-focus, non-contact IR thermometer measures the temperature of electronic components as small as 0.1-in. with pinpoint accuracy. Compact and lightweight, the instrument provides a large LCD and a bright dual-laser aiming system that allows for accurate aiming. Features include a measurement spot size of 2.5-mm in diameter at distances up to 18 mm, measurement range from -55ºC to +220ºC,(-67-428 deg F) an accuracy of ±2% of reading or ±2ºC whichever is greater, a repeatability of ± 0.2ºC, display resolution of 0.1ºC, and a response time of 1s. Operating with two AAA batteries providing 18 hours of continuous use, the instrument measures

SPECIFICATIONS:

Measurement Spot Size: 0.1-inch (2.5mm) diameter at 0.7" (18mm) distance

Temperature Measurement Range: -67º to 428 ºF (-55º to 220ºC)

Accuracy: ±2% of reading or ±2ºC (whichever is greater)

Repeatability: ± .2ºC

Display resolution: 0.1ºC

Response time: 1 second

Bright, built-in Class II dual-laser provides pinpoint aiming accuracy. Easy-to-read LCD display with built-in clock.

Emissivity (adjustable from 0.05 to 1.00) is preset for electronic component temperature applications

Back-lit LCD display, select ºC or ºF, Auto Off

Uses 2 AAA batteries providing 18 hours of continuous use

Weight and Dimensions: 4.5 oz., 1" x 6.7" x 1.6"

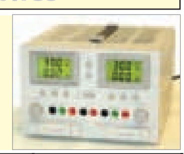
Item # **TN01U**

$129.00

This is the most advanced infrared thermometer manufactured today providing fast, accurate, non-contact component temperature measurements for hardware designers, Test, QA and Service professionals.

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA



Item #:	Price 1-4	Price 5+
CSI3003X3 0-30Vx2@3A	$198.00	$193.00
CSI3005XIII 0-30Vx2@5A	$259.00	$244.00

CircuitSpecialists.com

BlackJack SolderWerks

Premium Line Up for Soldering, Repair & Rework

Rugged design at an affordable price..BlackJack SolderWerks from Circuit Specialists Inc. is the industry cost/performance leader and continues our reputation of providing high value products to our customers.

Premium All-In-One Repairing Solder System BK6000

The BlackJack SolderWerks BK6000 Repairing System is a digital multipurpose reworking system that incorporates a Hot-Air Gun, Soldering Iron, (compatible with leaded solder or lead free solder), with integrated smoke absorber and a desoldering Gun.

$249.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK4000 *Thermostatically controlled desoldering station*

The BlackJack SolderWerks BK4000 is a thermostatically controlled desoldering station that provides low cost and solid performance to fit the needs of the hobbyist and light duty user. Comes with a lightweight desoldering gun.

$149.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

Hot Air with Vacuum I.C. handler & Mechanical Arm BK4050

The BlackJack SolderWerks BK4050 is designed to easily repair surface mount devices. Its digital display & tactile buttons allows easy operation & adjustments. The BK4050 includes a hot air gun and a vacuum style I.C. handler.

$169.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK5000 *Hot Air System w Soldering Iron & Mechanical Arm*

The BK5000 from BlackJack SolderWerks provides a very convenient combination of hot air & soldering in one compact package. The hot air gun is equipped with a hot air protection system providing system cool down & overheat protection.

$159.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

Compact Soldering Station BK2000

The BlackJack SolderWerks BK2000 is a compact unit that provides reliable soldering performance with a very low price. Similar units from other manufacturers can cost twice as much. A wide range of replacement tips are available.

$44.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK3000LF *Digital Display Solder Station for Lead Free Solder*

The BK3000LF is a compact unit designed to be used with lead free solder that provides reliable performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

$88.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

Compact Digital Display Solder Station BK2000+

The BK2000+ is a compact unit that provides reliable soldering performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

$59.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack

Limited Time Offer Free `BK486'

Fume Extractor with ANY BlackJack SolderWerks Station Purchase.

BK468

A $27.99 Value!

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